

BULLETIN
of **CARNEGIE MUSEUM OF NATURAL HISTORY**

**PALEONTOLOGY AND GEOLOGY OF THE
BADWATER CREEK AREA, CENTRAL WYOMING.
PART 16. THE CEDAR RIDGE LOCAL FAUNA
(LATE OLIGOCENE)**

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ABSTRACT

Upper Oligocene strata unconformably overlying upper Eocene sediments outcrop along Badwater Creek, in central Wyoming. The fauna from the underlying Eocene sediments has been collected and studied by Carnegie Museum of Natural History since 1962. Late Oligocene mammals were first recognized in the overlying sandy facies during the 1964 field season by field parties of Carnegie Museum.

Intensive collecting and use of screen washing techniques have resulted in the recognition of 26 mammal genera. Most of the fossils recovered are fragmentary, and are generally less than 3 mm in size, which indicates considerable transport of the material. This assemblage of animals is biased by two major factors. First, due to stream sorting, only small teeth and bones were deposited so that larger mammals, which surely lived near the site of deposition at that time, are not represented in the fauna. And second, the local climate was dry and of moderate temperature. This is indicated by the presence of calcic feldspars and gypsum crystals throughout the section. Due to the dry climatic conditions, only land mammals, which were adapted to this ecological situation, could live there and consequently these animals are represented in the present fauna. On the other hand, the animals, which required a more mesic condition, could not have lived there and consequently they are not represented in the

fauna. Currently sampled upper Oligocene deposits along Badwater Creek do not preserve the real diversity of late Oligocene mammals.

Due to the less favorable ecological conditions, land micro-mammals, which lived there in the late Oligocene, were specialized in having higher crowned and more lophate teeth. The evolution of this type of dentition was the result of the adaptation to a more herbaceous diet in a drier climatic situation. Some rodents represented had more hypsodont teeth than did their middle Oligocene counterparts, but they had not yet developed rootless or ever-growing cheek teeth. Near the Oligocene-Miocene boundary, the climate returned to more mesic conditions and these highly specialized rodents, which were adapted to drier conditions, could not have survived and either became extinct or migrated to other areas by the end of the Oligocene.

During the early Miocene, a few rodents migrated into North America from Eurasia. These are not direct descendents of the late Oligocene rodents of North America. All the late Oligocene micromammals of North America have their ancestry in the middle or early Oligocene of North America. Based on the micromammal assemblages, the faunal gap between the late Oligocene and the early Miocene is greater than the one between the middle and late Oligocene in North America.

INTRODUCTION

Since 1962, the Section of Vertebrate Fossils of Carnegie Museum of Natural History has been working Tertiary deposits and collecting vertebrate fossils along Badwater Creek in the northeastern part of the Wind River Basin, Natrona and Fremont counties, central Wyoming. The University of Colorado Museum, the Museum of Natural History of the University of Kansas and The Museum of Texas Tech University cooperated with this work in various ways. A considerable number of vertebrate fossils has been recovered in volcanic rich silts and clay along Badwater Creek. These sediments were thought to be eastern equivalents of the Tepee Trail Formation (Tourtelot, 1957). There is now almost overwhelming evidence that these sediments do not represent the Tepee Trail Formation (Krishtalka and Black, 1975), but until a thorough geologic review of the area can be completed, Tourtelot's usage is followed. The vertebrates recovered from these deposits are primarily of the late Eocene age although other faunal levels are also recognized. Much of the fauna has been described since 1966.

In 1964, a field party from the Carnegie Museum of Natural History discovered a much later faunal level in the tan silts, which unconformably overlie "the Tepee Trail Formation" along Badwater Creek. Recovery of vertebrate fossils from this level was continued by field parties from the University of Kansas in 1971 and from Texas Tech University in 1973 and 1974. As in many other early Cenozoic assemblages, most vertebrates in the later faunal level in Badwater Creek area are represented by fragmentary remains, generally consisting of isolated or loosely associated teeth. More than fifteen hundred identifiable specimens are at hand. These specimens are described below.

The present study is a part of a series of studies of the Badwater fauna. Most of the materials dealt with were collected by me during the field season of 1974, and some by field parties of Carnegie Museum of Natural History and the University of Kansas.

The abbreviations used in this paper are as follows: CM, Carnegie Museum of Natural History; KU, University of Kansas; L, length; W, width; AW, anterior width (width of trigonid); PW, posterior width (width of talonid).

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Dr. Black, and Dr. Mary R. Dawson (Carnegie Museum of Natural History, Pittsburgh) originally suggested this study to me as a significant subject for a doctoral dissertation in vertebrate paleontology, and provided general access to and loan of fossil material in their care.

I am also grateful to them and to the following people for thoughtful and stimulating discussion concerning Tertiary insectivore, rodent, and lagomorph evolution: Dr. John F. Sutton and

Dr. Leonard Krishtalka, both at Carnegie Museum of Natural History; Dr. Robert W. Wilson and Dr. Larry D. Martin at the University of Kansas, Lawrence.

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PREVIOUS WORK

The presence of mid- or later Tertiary strata along the Badwater Creek area was recognized as early as 1948. In the 1948 Guidebook for the Third Annual Field Conference of the Society of Vertebrate Paleontology, Tourtelot (p. 66) briefly mentioned a sequence of soft, tan, ashy siltstone with two beds of vitric tuff which occur along Badwater Creek overlying the late Eocene Tepee Trail Formation in Secs. 23 and 24, T39N R89W, Natrona County, Wyoming. He referred to these rocks as "uppermost Eocene or Oligocene (?) and Younger . . .," and said that the siltstone was remarkably similar to Miocene rocks in other parts of Wyoming but there was "little" break between the Tepee Trail Formation and this siltstone sequence. Later (1957) he referred to this tan siltstone sequence as the upper part of the Hendry Ranch Member of the Tepee Trail Formation. Thus, the Hendry Ranch Member defined by him (1957) includes all the strata, which overlie the Green and Brown Member in the Badwater area.

No fossils were known from these rocks until 1964 when a Carnegie Museum of Natural History field party discovered a vertebrate fauna in the NW $\frac{1}{4}$, Sec. 24, T39N R89W (locality 19 of Black and Dawson, 1966:303). The tan silt sequence was pros-

pected in 1965 and some two tons of matrix were washed from locality 19 in 1966 by Carnegie Museum of Natural History field parties. Vertebrates recovered from locality 19 were then designated the Cedar Ridge local fauna (Black, 1968:51). When identifiable remains are recovered higher in the section along Badwater Creek, they will be of a later age and therefore the use of the name "Cedar Ridge local fauna" must be restricted to the assemblage found at locality 19. The use of "Badwater local fauna" is restricted to the assemblage found in the Upper Eocene Hendry Ranch Member below the Oligocene strata.

Riedel (1969) recognized an unconformity within Tourtelot's Hendry Ranch Member. Vertebrates at locality 19 are found in the tan tuffaceous siltstones above the unconformity.

Prospecting at locality 19 was continued by field parties from the University of Kansas in 1971 and Texas Tech University in 1973 and 1974. I started work on the geology and paleontology of the Cedar Ridge local fauna after 1974.

Brief accounts of the geology and vertebrate fossils of the Cedar Ridge local fauna are to be found in Black (1968, 1969) and Riedel (1969).

COLLECTING METHODS

All the fossils were collected from one locality. The matrix containing fossils is weakly cemented by carbonate. Normal washing and screening methods are not applicable for this matrix as it is not easily disintegrated because of the cement. I used citric acid to desolve the calcareous cement.

After quarrying, all the matrix was dried and broken down, and the concentrates were then soaked in a weak solution of citric acid (3-5 weight percent). Reaction between the calcareous

matter and citric acid lasts almost two days. The matrix was soaked in the citric acid twice to desolve the calcareous cement completely. After dissolving the calcareous cement, normal washing and screening methods were used.

When fossils are soaked in a strong solution of citric acid (for example 25 weight percent) for one day, they are damaged by the acid. I used a weak solution to avoid damaging the fossils.

GENERAL GEOLOGY

The area of the present study is located in the northeastern part of the Wind River Basin along the

southern edge of the Big Horn Mountains and the southeastern end of the Owl Creek Mountains in

Natrona County, Wyoming. All the fossil localities along Badwater Creek of both late Eocene and younger age lie to the south of Badwater Creek between the creek and the Cedar Ridge fault.

Love (1939) proposed the name Tepee Trail Formation for a sequence of volcanic tuffs and flows of late Eocene age in the East Fork Basin near the southeast margin of the Absaroka Range. Tourtelot (1948, 1957) applied this name to a sequence of volcanic-rich sedimentary rocks along the southern margins of the Owl Creek and Big Horn Ranges. He subdivided the Tepee Trail Formation into two members, a lower Green and Brown Member and above this the Hendry Ranch Member. The Hendry Ranch Member defined by Tourtelot (1957) includes all the strata, which overlie the Green and Brown Member in the Badwater area. Black (1968, 1969) reported the discovery of late Oligocene vertebrates from a tan siltstone sequence at the top of the Hendry Ranch Member. During his study of the geology of the Badwater Creek area, Riedel (1969) recognized an unconformity within the Hendry Ranch Member between the gray and buff tuffaceous mudstones from which late Eocene vertebrates were obtained and the tan tuffaceous siltstones and sandstones from which late Oligocene vertebrates were obtained. He proposed to restrict usage of the Hendry Ranch Member to the gray and buff tuffaceous mudstones, especially excluding the tan tuffaceous siltstones and sandstones, which lie unconformably above them. The vertebrates discovered from the latter sediments are dealt with here.

The gray and buff tuffaceous mudstone along Badwater Creek from which late Eocene vertebrates were found has been classified as the Tepee Trail Formation (Tourtelot, 1957). There is now almost overwhelming evidence that these sediments do not represent eastern equivalents of the Tepee Trail Formation. Rather, these volcanic rich silts and clay were probably deposited at the same time as, or somewhat later than, the volcanic conglomerates of the Wiggins Formation, which overlies the Tepee Trail Formation in its type area. This problem is outside the scope of the present study. Because a thorough geologic review of the area has not been completed as yet, I shall continue to follow Tourtelot's usage.

Tentatively, I assign the deposit to the Oligocene strata, which include the tan tuffaceous siltstones and sandstone from which late Oligocene vertebrates were obtained. The best exposures are in NE Sec. 24, T39N R89W where more than 200 ft of strata

are exposed and an additional 500 ft are concealed by overlying Quaternary gravel and vegetation. The lower contact here is marked by an angular unconformity of approximately 2 degrees and erosional relief of up to 40 ft. The top of the unit is truncated by erosion throughout the area. The Oligocene strata and the Hendry Ranch Member of the Tepee Trail Formation are down faulted against the Green and Brown Member, or against the Lost Cabin and Lysite Members of the Wind River Formation along the course of Badwater Creek and the Cedar Ridge. This fault, called the Cedar Ridge fault, can be traced roughly from ESE to WNW throughout the area.

A general geologic map of the Badwater Creek area is shown in Fig. 1. A structural cross section near the late Oligocene fossil locality is shown in Fig. 3. Below the unconformity are the gray and buff tuffaceous mudstones of the Hendry Ranch Member of the Tepee Trail Formation. The erosional relief ranges up to 40 ft. The bottom of the relief (the point A in the Fig. 3) represents a stream channel. At the point A, conglomerates of medium pebble size are deposited. The maximum thickness of the conglomerates is 3 cm. The transverse (perpendicular to the stream course) extension of the conglomerates is 7 m or so, and the layer is lenticular. High on the sides of the relief surface at point B, conglomerates are not observed, and here the fine-grained sandstones of the Oligocene strata lie directly on the tuffaceous clay of the Hendry Ranch Member.

The relief is lower to the east of the old stream channel. Here the erosional relief is approximately 10 ft or less. At the point C, about 2 ft above the contact with underlying Hendry Ranch Member is a vitric tuff with a thickness of about 1 m. The tuff is traceable laterally so that it is used as a marker bed. Laterally, it thins and is about 0.5 m above point A. Geochron Laboratories, Inc. used potassium-argon ratios to determine the age of the vitric tuff at point C (Riedel, 1969). This age was given as 34 million years and falls within the lower Oligocene as delimited by Kulp (1961) and Evernden and others (1964). If the age determination is valid, it indicates that these lowest beds were deposited during early Oligocene time.

Above the vitric tuff are siltstones and fine-grained sandstones about 24 m thick. Cross-bedding and truncate bedding are predominant in the fine-grained sandstones. A calcareously cemented lens of siltstone (Loc. 19) is found about 12 m above the

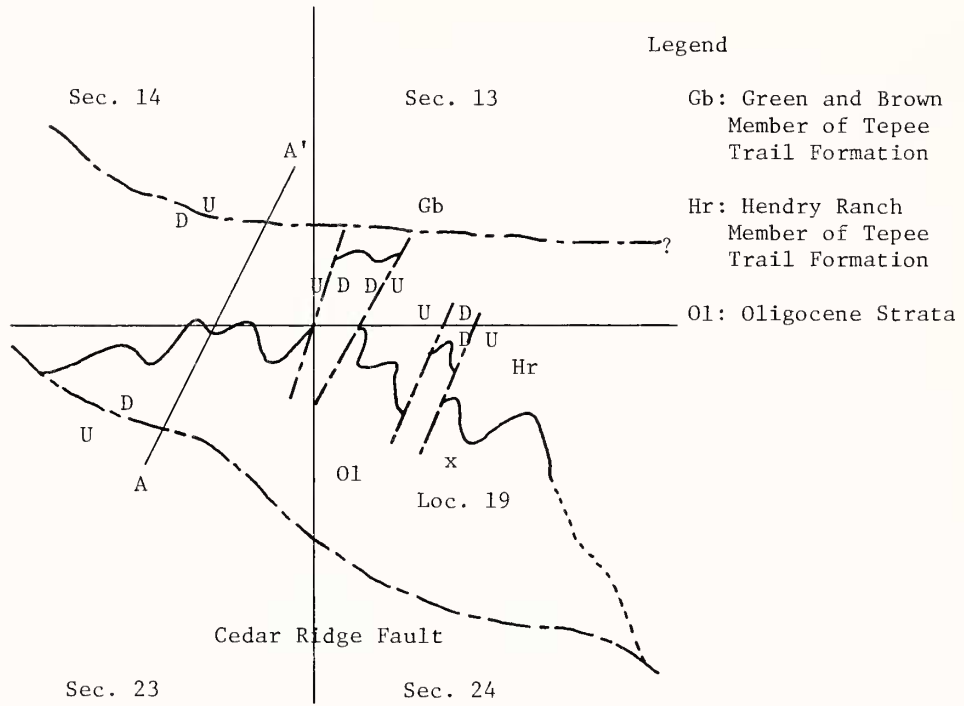


Fig. 1.—Simplified geologic map along Badwater Creek, at Secs. 13, 14, 23, & 24, T39N, R89W, in Natrona County, Wyoming. Scale—1:24,000.

vitric tuff. A number of vertebrate fossils have come from this calcareous lens. Below the lens and above the vitric tuff are predominantly fine-grained sandstones, and the homogeneity of the sequence indicates that no depositional breaks are represented within this sequence of sandstones. The vertebrate fauna is inferred to be of late Oligocene age. The radiometric determination of an age of 34 million years for the vitric tuff does not correlate well with the postulated age of the fauna. Although they

are separated stratigraphically by 12 m, I could find no evidence for the presence of a depositional break, or a hiatus between the tuff and the fossiliferous lens. I believe that the potassium-argon age determination is in error and is too old. I can not believe that the section preserved north of the Cedar Ridge fault consists of a thin sequence representing early Oligocene deposition, a long depositional hiatus and then the resumption of deposition in late Oligocene time.

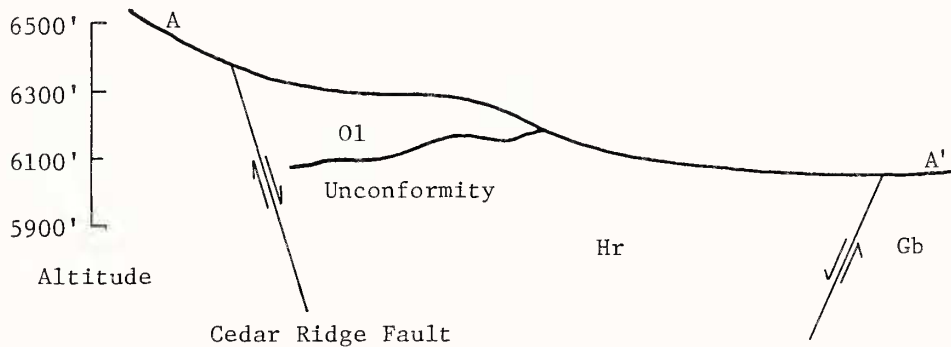


Fig. 2.—Cross section along A-A' shown in the Fig. 1. Horizontal scale—1:8,000. Vertical scale—1:6,000.

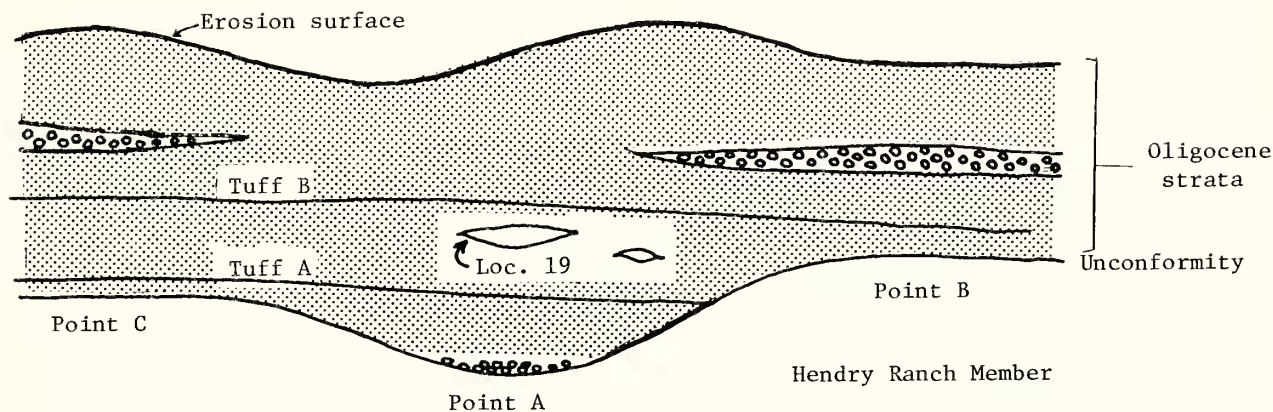


Fig. 3.—Structural cross section near the late Oligocene fossil locality, Loc. 19, at Sec. 24, T39N, R89W, in Natrona County, Wyoming. Horizontal scale—1:5,000. Vertical scale—1:2,000.

A hard gray tuffaceous sandstone lies 1 m above the siltstones and sandstones and can be used as a marker bed. One and one-half m above the sandstone there is a pebble to cobble sized conglomerate. The thickness is about 30 to 40 cm and its distribution is quite wide. The conglomerate represents deposition on a flood plain. The direction of the current at the time of deposition of the conglomerates is determined by the direction of axes of elongated cobbles—from SW to NE. The pebble and cobbles consist of Precambrian gneisses and granites,

sandstones and limestones of the Paleozoic, and re-worked siltstones of underlying Oligocene strata. The average diameter of the pebbles is 5 cm. Based on the direction of the current, uplift had taken place to the southwest of Badwater Creek. Rapid erosion of Precambrian and Paleozoic rocks and transportation toward the northeast cause the deposition of the conglomerates in Badwater Creek area.

All the strata mentioned above dip gently southward (about 10°).

FAUNAL LIST

The following is the list of the amphibians, reptiles, and mammals identified in the Cedar Ridge local fauna.

Class Amphibia

Order Urodela

Family Batrachosauroididae

? *Batrachosauroides* sp.

Class Reptilia

Order Sauria

Family Iguanidae

Leiocephalus sp.

Class Mammalia

Order Marsupicarnivora

Family Didelphidae

Peratherium sp. cf. *P. spindleri* Macdonald, 1963

Nanodelphys new species, unnamed

Order Insectivora

Family Leptictidae

Leptictis sp.

Family Adapisoricidae

Ankyledon sp. cf. *A. annectens* Patterson & McGrew, 1937

Family Geolabididae

Centetodon sp. cf. *C. marginalis* (Cope, 1974)

Family Soricidae

Domnina sp. cf. *D. gradata* Cope, 1873

Family Talpidae

Proscalops miocaenus Matthew, 1901

Oligoscalops ? sp.

Family Micropternodontidae

Micropternodus sp.

Order Rodentia

Family Aplodontidae

Prosciurus relictus (Cope, 1973)

Pelycomys placidus Galbreath, 1953

Family Eomyidae

Adjidaumo douglassi Burke, 1934

Paradjidaumo hysodus, new species

Metadjidaumo hendryi, new genus and new species

Eomyidae, genus indet., Type A

Eomyidae, genus indet., Type B

Family Heteromyidae

Proheteromys sp. cf. *P. nebraskensis* Wood, 1937

Heliscomys sp. cf. *H. vetus* Cope, 1873

Family Cricetidae
Eumys parvidens Wood, 1937
Eumys elegans Leidy, 1856
Eumys brachyodus Wood, 1937
Eumys sp. cf. *E. planidens* Wilson, 1949
Order Lagomorpha
Family Leporidae
Palaeolagus burkei Wood, 1940
Palaeolagus sp. cf. *P. intermedius* Matthew, 1899
Order Carnivora
Family Canidae
Hesperocyon tenuodon (Wortman & Matthew, 1899)

Order Perissodactyla
Family Equidae
Miohippus sp.
Family Hyracodontidae
Hyracodontidae genus indet.
Order Artiodactyla
Family Hypertragulidae
Leptomeryx sp. near *L. evansi* Leidy, 1853
Hypisodus sp. near *H. minimus* (Cope, 1873)

MAMMALIAN TAXA ABSENT FROM THE CEDAR RIDGE LOCAL FAUNA

The Cedar Ridge local fauna is represented by a sufficient number of identifiable specimens to make it worthwhile to consider prominent absences from the known mammalian fauna. A good many forms are absent from the Cedar Ridge local fauna. The reasons for the absence of some taxa, I believe, should be considered from the following two points of view. First, some forms were surely living at the time of deposition in the area where the Cedar Ridge local fauna has been recovered, but for some reasons they were not fossilized there. Second, the other forms could not have lived in the Badwater Creek area so that they are not represented in the present fauna.

The remarkable absence of larger forms, such as ungulates and carnivores, could be explained according to the first reason mentioned above. As I explained in the section of the paleoecological setting of the sites, the climate of the area during the late Oligocene was drier than the middle Oligocene and is thought to have been grassland, steppe to semidesert. This is supported by the presence of gypsum crystals throughout the section. Schultz and Falkenbach concluded that the leptauchine oreodonts (tribe Leptaucheniini) lived in very arid, desert-like regions (Schultz and Falkenbach, 1968:407). They stated (1968:408), "The Leptaucheniini apparently were well adapted to the unfavorable climatic conditions of the late Oligocene and were able to survive in great numbers, but most of the other kinds of oreodonts either became extinct or lived in areas where the climate was more hospitable. Evidently the hyracodont rhinoceroses also had specialized in such a manner as to live in arid desert areas. Most of the other mammals must have found it difficult to survive, and migrated elsewhere, or lived along the banks of small streams

that existed in the area at that time. The Leptaucheniini were well adapted for dwelling in deserts. The same was apparently true of the hyracodonts." I think that surely leptauchine oreodonts and hyracodont rhinoceroses were living in the Badwater Creek area during the late Oligocene time. No oreodonts are represented but a few unidentifiable rhinoceros tooth and bone fragments are found in the fauna. The fossils found at Loc. 19 are mostly isolated teeth and jaw fragments. The nature of preservation indicates that teeth and bones were transported some distance after the death of animals and before the time of final burial. Moreover, the size of most teeth and bones found there are less than 3 mm in longest diameter, and specimens over 5 mm are very scarce. This type of preservation indicates that the material deposited were well sorted by stream action. The teeth and bones of larger size are not suitable for distance transport and were not deposited there. By this sorting mechanism, no oreodonts were transported and deposited at the site where the Cedar Ridge local fauna was recovered. The occurrence of *Hypisodus* in this fauna is meaningful. A few teeth referable to *Hypisodus* are found teeth. The size of these teeth is at the upper limit of the size range of teeth found at Loc. 19. The species of *Hypisodus* are the smallest of known artiodactyls, indicating that only the teeth of the size of the smallest artiodactyls could be transported. This is true for perissodactyls and carnivores. Galbreath (1953) reported 10 genera of ungulates and carnivores from the Vista Member of the White River Formation of northeastern Colorado. In the present fauna, only three genera are represented and they are very scarce in comparison with the other smaller forms.

The absence of some insectivores and rodents in

the present fauna must be explained by unfavorable ecological conditions for them in the Badwater Creek area. *Scottimus* has been reported from the late Oligocene in the Great Plains (in Nebraska) but this form was not found in the present fauna. *Leidyms* and *Pacculus* are known from the late Oligocene of Oregon but they are not represented in the Badwater Creek area. Interestingly enough, they did not become extinct at the beginning of Miocene time but they continued to survive into the Miocene in the Rocky Mountain region, that is in Montana, Colorado, and Wyoming. Their ancestral forms are known in the middle Oligocene of the Great Plains. These forms all have lower-crowned teeth and probably lived in a more mesic habitat. Most small mammals in the present fauna have high-crowned teeth or teeth with high, thin cross-lophs. The trend towards higher-crowned teeth is perhaps an adaptation for a typical herbaceous diet in a dry environment. The animals, which required a more mesic habitat, are not represented in the present fauna. Martin (1972) clearly described the evolutionary pattern of cricetid rodents in relation to the climatic changes; the steppe forms became extinct near the Oligocene-Miocene boundary. This extinction may be related to a return of mesic conditions and the subsequent expansion of the genera *Leidyms* and *Pacculus*. This is the most probable explanation as to why *Leidyms*, *Pacculus*, and *Scottimus* were not represented in the late Oligocene in the Rocky Mountain region but occur there in Miocene time. Oregon, from which *Leidyms* and *Pacculus* are reported in the late Oligocene, was a

costal area and was under a milder climatic regime throughout the Tertiary period. *Scottimus* is also supposed to have lived near stream banks during the late Oligocene and becomes abundant once the climate returned to a more mesic condition in the Miocene. The ecological requirements of *Trimylus* and *Domnina* are not certain. *Trimylus* has a more bulbous, less high crowned condition of the teeth (Repenning, 1967) than *Domnina*. The presence of *Domnina* and the absence of *Trimylus* in this fauna seems to be analogous to the presence of rodents with higher-crowned and the absence of those with lower-crowned teeth. The relative abundance of *Eumys planidens*, which has more lophate teeth, may be explained in the same way. All the eomyids and the most of the cricetine *Eumys* species became extinct without leaving any descendants. I believe that pseudotheridomyine rodents known from the Miocene of North America are not descended from the North American Oligocene eomyids but represent immigrants from the Old World. The extinction of many eomyids and cricetids in North America by the end of the Oligocene may be related to a return of mesic conditions as Martin (1972) stated.

The Cedar Ridge local fauna represents a fauna adapted to a drier environment and is biased due to sorting by stream action. For these reasons, a good many forms are absent from the fauna. This leads to the conclusion that currently sampled Whitneyan deposits in the Badwater Creek area do not preserve the real diversity of the late Oligocene mammals.

AGE OF THE STRATA

As noted above, the Oligocene strata lie unconformably above the late Eocene clay. The overlying siltstones and sandstones are of the upper Oligocene age as indicated by the occurrence of the late Oligocene fauna. We obtained the K-Ar age for the Tuff A as 34.3 ± 1.4 m.y. This age falls into the early Oligocene as delimited by Kulp and Evernden. The determination of the age for the tuff does not correlate well with the fauna. I believe that the K-Ar age given is too old. If it is correct, no middle Oligocene strata are represented in the Badwater Creek area.

In the Wind River Basin and surrounding area, epirogenic uplift began after Eocene time. For the Oligocene of Wyoming, van Houten (1964:71) stated, "Reduced relief resulted in the slow accumu-

lation of stream-laid deposits; however, numerous showers of ash from vents in the Yellowstone-Ab-saroka volcanic field contributed a substantial amount of sediment. Altered ash that mantled the uplands supplied most of the mud that was spread as an almost continuous sheet on flood plains over much of Wyoming and the adjacent Great Plains." These sediments of the Oligocene consist of the White River Formation in Wyoming and Colorado, or the White River Group of the Great Plains.

The Oligocene strata along Badwater Creek are separated from the Eocene strata by only a modest angular (about 2°) and erosional unconformity. This indicates that no severe orogenic disturbance was represented in this region during the period of time between the time of deposition of the Hendry

Ranch Member and that of the Oligocene strata. I believe that volcanic ash from vents in the Yellowstone-Absaroka volcanic field were deposited in this region, but that these sediments were eroded and the erosion acted on the clay of the Hendry Ranch Member. By late Oligocene time, the drainage system was changed and upper Oligocene strata were deposited along this new drainage system. These sediments were first accumulated as channel fillings and later as flood plains deposits.

Along Badwater Creek, no lower and middle Oligocene strata correlative to the White River Formation are observed. A sequence of sediments of early Oligocene age occurs along Beaver Rim on the southern edge of the Wind River Basin, 50 mi southwest of the Badwater Creek area. The sediments along Beaver Rim are referred to the White

River Formation (van Houten, 1964). Once the lower part, at least, of the Oligocene strata of the Badwater Creek were believed to be of the early Oligocene age because of the age of the Tuff A given as 34 m.y. and because the lower Oligocene sequence occurs along Beaver Rim (Black, 1969:45). As I stated before, I could not find any evidence of a break in deposition, or hiatus between Tuff A and the calcareous lens (Loc. 19 of Carnegie Museum of Natural History) from which the late Oligocene vertebrates are obtained.

For these reasons, I consider the potassium-argon age determination is too old. All the sediments were accumulated in the late Oligocene as indicated by the occurrence of vertebrates of the late Oligocene age.

CORRELATION OF THE STRATA

In the Beaver Rim area, the White River Formation is well developed. The thickness of the formation varies locally; the formation reaches its maximum exposed thickness of approximately 650 ft along the Beaver Rim in the vicinity of Cameron Springs and may have been as much as 800 ft thick 2.5 mi north of the divide (van Houten, 1964:55-56). In this area, the White River Formation yields mammalian fossils of early (Chadronian) and possibly of middle (Orellan) Oligocene age. Van Houten (1964:71) concluded that, "There is no clear evidence of deposits of late Oligocene age in the southern part of the Wind River Basin."

The Oligocene strata of the upper Oligocene along Badwater Creek are not directly correlative with the White River Formation in the Beaver Rim area. As far as I know the Vista Member of the White River Formation in Logan County, northeastern Colorado (Galbreath, 1953) and the Whitney Member in Nebraska and South Dakota are the only known deposits, which yields vertebrate fossils of late Oligocene (Whitneyan) age. These beds are composed of massive, tan silt with a highly calcareous zone. The thickness is about 100 ft and the areal extent probably is not large (50 to 75 square

mi). The Vista Member can be distinguished faunally and lithologically, but it should be emphasized that the lithologic separation from the (underlying) Cedar Creek Member of the White River Formation is largely arbitrary. Were the fauna not known, the lithologic differences would have no stratigraphic significance.

Although the Vista fauna is scanty, the fossils are individually rare, the late Oligocene Badwater fauna is correlative with the Vista fauna. Lithologically, the well laminated appearance of the Oligocene strata in the Badwater Creek area is quite different from the massive nature of the Vista Member in Colorado. It is not certain whether the upper Oligocene deposits in the Badwater Creek area and in northeastern Colorado accumulated in different structural basins or not, but if they were deposited in different basins, they should be assigned to different formations. This problem is beyond the scope of the present work. Although I believe that the Oligocene strata along Badwater Creek may be assigned to the White River Formation but to a different member, I leave it unnamed until a thorough geologic study of this area is completed.

FAUNAL AGE

The late Oligocene, or Whitneyan, mammalian faunas of North America are not well known. An age determination for a micromammalian assem-

blage such as the present fauna is complicated by the fact that we have only the haziest idea as to other late Oligocene small mammal faunas. Of some

40 genera of mammals known from the upper part of the Brule Formation in Nebraska, South Dakota, and Colorado, and considered to be late Oligocene in age, only one-fourth are in the "micro" mammal range. Galbreath (1953) described several mammals of the late Oligocene from the Vista Member of the White River Formation of northeastern Colorado. But the Vista fauna is scanty, and the fossils are individually rare.

A late Oligocene age for the present fauna is based upon the following data.

(1) *Marsupials*.—*Peratherium* and *Nanodelphys* are typically early Tertiary genera ranging from the mid-Eocene to the early Miocene. As far as the specific level is concerned, the species of *Peratherium* and *Nanodelphys* are intermediate between the middle Oligocene and the early Miocene forms. Based on marsupials alone, it is fairly safe to conclude that the age of the fauna is post-middle Oligocene and pre-early Miocene.

(2) *Insectivores*.—*Ankylodon*, *Centetodon*, and *Micropternodus* are typically Oligocene genera, although *Centetodon* and *Micropternodus* are known from the early Miocene of Nebraska and Oregon. *Proscalops* and *Domnina* are known from the middle Oligocene for the former and from the late Eocene for the latter into the early Miocene. Of the five genera, one is known only from the Oligocene and four from the mid-Oligocene into the early Miocene. At the specific level, all the species of the present fauna are a little advanced over the middle Oligocene species and are not conspecific with any of the known early Miocene species. This is also suggestive of a late Oligocene, or at least pre-Miocene, age for the fauna.

(3) *Lagomorphs*.—The occurrence of *Palaeolagus intermedius* is not well documented. The other species of *Palaeolagus* is intermediate between *P. burkei* of the middle and late Oligocene and *P. hypsodus* of the earliest Miocene, although it is a little closer to the former. *P. hypsodus* is known from the Gering Formation in Nebraska and Wyoming and from the Sharps Formation of South Dakota both considered to be basal Miocene in age. The present population is not as advanced as this species and would therefore suggest a latest Oligocene age for the fauna.

(4) *Rodents*.—*Pelycomys* is known from the Oligocene. At the specific level, this form is close to the middle Oligocene species. *Adjidaumo* and *Paradjidaumo* are typically Oligocene genera. At the specific level, *Paradjidaumo* in the present fauna is advanced over the middle Oligocene *Paradjidaumo*. It is suggestive of a post mid-Oligocene age for the fauna. The other eomyids differ from the typical Oligocene *Adjidaumo* and *Paradjidaumo* genera but are certainly closely related to them and show no resemblance to the Miocene *Pseudotheridomys*. *Prosciurus*, *Heliscomys*, *Proheteromys*, and *Eumys* are all known from the earliest Miocene but are more typical, abundant, and diverse in the Oligocene. The absence of beavers, mylagaulids, and aplodontids (beside *Prosciurus*) from the present fauna is meaningful. Their absence most probably reflects a different habitat preference. These three rodent families are almost always found in faunas of the early Miocene. They are known from the earliest Miocene of South Dakota, eastern Wyoming, and Nebraska but are unknown from the late Oligocene of these same areas.

PALEOECOLOGICAL SETTING

The Oligocene strata were accumulated as channel-fill. The lower part of the sequence seems to be one of over-filling of the previously eroded valley. Aggradation was greater than erosion. Granites and gneisses, sandstones and limestones, and mud balls from the underlying Hendry Ranch beds are common in the gravel lenses near the base of the unit. As sedimentation proceeded, the previously eroded valley was filled by sediments, and sediments were deposited on a broader flood plain. Well sorted, laminated and truncated sandstones indicate that sedimentation took place in a braided stream situation.

Paleosols are not recognized in the Oligocene strata. Andesine is the most common feldspar throughout the section. In a calcareous lens from which the late Oligocene vertebrates are found, bytownite and probably anorthite are present. X-ray diffraction patterns of the sample from the same calcareous lens also indicate that feldspars preserved are calcic (Hattori, personal communication). The presence of fresh, calcic feldspar indicates that the sediments were not heavily weathered, and the paleoenvironment should have been open land or grassland type with moderate temperature. This conclusion is strengthened by the presence of

gypsum crystals throughout the section. The texture of gypsum crystals is fine to medium grained. They occur in beds with disturbed bedding. This seems to be due to expansion during hydration. Gypsum is usually formed at lower temperatures, whereas anhydrite is precipitated at temperatures above 30° C. The presence of evaporites indicates the climate was rather dry at the time of deposition. This is consistent with other evidence that the climate became progressively drier towards the late Oligocene in the Great Plains (Schultz and Falkenbach, 1968).

The origin of calcareous lenses is uncertain. The siltstones and sandstones are essentially noncalcareous throughout the section. In the Great Plains near the type locality of the Whitney Member, most of the fossils found in the Middle and Upper Whitney sediments are enclosed in clay-siltstone nodules, which are cemented by calcium carbonate, and the nodules must have been formed by the action of ground water (Schultz and Falkenbach, 1968:408). This is not the case for the Oligocene sediments along Badwater Creek. There, calcareous lenses are rare and only two calcareous lenses have been found so far. Both of them are fossiliferous. The non-calcareous nature of the siltstone and sandstone may argue against the process of the formation of the calcareous lenses by the action of ground water. The calcium carbonate may have been accumulated in small playa lakes on the flood plain and vertebrate bones and teeth were transported in these lakes. The vertebrate remains are well preserved because the lenses are resistant to weathering or to stream action. Vertebrate fossils are found only in the calcareous lenses, and are not found in the siltstones and sandstones.

The sedimentary structure through the whole section is predominated by the high degree of sorting, cross-bedding, and truncated bedding. All the sandstones are fine-grained and pebble size grains are observed only in conglomerate layers. The sediments were accumulated under running water with rather low energy. The fossil teeth and bones found at Loc. 19 are isolated and abraded, and the diameter of these are mostly less than 3 mm. No bones in articulation are found. The nature of preservation of the fossils indicates that these teeth and bones were transported some distance before final burial by running water, and due to the energy of running water the materials transported were well sorted. Only a few larger bones were deposited near Loc.

19. This sorting mechanism of stream action greatly influenced the kinds of mammals buried and preserved at Loc. 19. The larger mammals, if they lived near the site of deposition, would have been not easily transported and buried there after their death.

During the middle Oligocene, the White River Formation was developed over a vast area east of the ancestral Rocky Mountains in Wyoming, Colorado, South Dakota, and Nebraska. These deposits are typically flood-plain sediments accumulated under a climatic regime of relatively high precipitation. Toward the end of Oligocene time, apparently precipitation became reduced and the aerial development of the White River Formation also became reduced. The aerial distribution of the late Oligocene sediments is greatly restricted and represented only in a few areas—the Vista Member in Colorado and the Whitney Member in Nebraska and South Dakota of the White River Formation. This restriction was caused by the reduced precipitation and subsequent reduced drainage systems in the Great Plains region. This interpretation is consistent with the climate becoming progressively drier in the late Oligocene (Schultz and Falkenbach, 1968; van Houten, 1964). The vegetation in the late Oligocene must have been of a steppe-type. In relation to the restricted distribution of the late Oligocene sediments, the late Oligocene mammal faunas are not well known except for the one from the type area of the Whitney Member of the White River Formation in Nebraska. The latter fauna is composed mostly of oreodonts.

In the early Miocene, climatic conditions apparently changed again to a period of more precipitation. The Arikaree group in Nebraska was deposited as channels cut through to the underlying middle Oligocene series in most areas. These sediments are mostly of the channel-filling type initially. The extensive development of the lower Miocene series reflects the return of the climate to a more mesic condition with greater precipitation and resultant development, or rejuvenation of drainage systems. The early Miocene must have been considerably more humid and the vegetation more luxuriant.

The climatic and environmental changes near the Oligocene-Miocene boundary caused a great difference in the composition of faunas between the late Oligocene and the early Miocene.

SYSTEMATIC ACCOUNTS

Class Amphibia

Order Urodela

Family Batrachosauroididae Auffenberg, 1958

? *Batrachosauroides* sp.

(Fig. 4)

Referred specimens.—Vertebrae, CM 33649 and uncatalogued specimens.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Discussion.—The vertebra is amphicoelous. When Taylor and Geese (1943) established a new salamander genus *Batrachosauroides* from the Miocene of Texas, they determined that the vertebrae were amphicoelous and not opisthocelous. The present specimen may be referred to this genus. Auffenberg (1958:170–171) argued about the genus *Batrachosauroides* and stated that the vertebrae referred to *B. dissimulans* are all strongly opisthocelous. At present, I cannot evaluate which statement should be more reasonable. Tentatively I followed Taylor and Hesse and I refer the present specimen to that genus.

Class Reptilia

Order Sauria

Family Iguanidae

Leiocephalus sp.

(Fig. 5)

Referred specimens.—Jaws; CM 33650 and uncatalogued specimens.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description and discussion.—The pleurodont teeth have tall, slim, and straight-sided shafts, except for a slight flaring toward the crown. The crown is flattened linguobuccally into a narrow tricuspid fan-shaped structure, the central cusp largest. Each side cusp is prominently separated from the main cusp by a wide groove, which fades out at the base of the crown. These grooves lack an associated ridge.

The present form may well be compared with *Leiocephalus* sp. described by Estes (1963:239) from the early Miocene Thomas Farm local fauna of Florida. As in Florida specimens, the grooves on the crown which separate side cusps from the main cusp lack an associated ridge, seen in many such lizard teeth, which extends from the apex of the lateral cusp to the base of the crown.

Class Mammalia

Infraclass Metatheria

Order Marsupicarnivora

Family Didelphidae Gray, 1821

Peratherium sp. cf. *P. spindleri* Macdonald, 1963

(Fig. 6, Table 1)

Referred specimens.—P³-M¹: CM 17085; M¹-M⁴: CM 33404; M²-M³: CM 33439; M¹: CM 33404–33438; M²: CM 33440–33462; M³: CM 33463–33479; M³: CM 33541–33544; M₁-M₂: CM 33480; M₂-M₃: CM 17080, CM 33481; M₁: CM 33482–33500; M₂: CM 33501–33520; M₃: CM 33521–33536; M₄: CM 17082, CM 33537–33540.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—The size of teeth is smaller than that of *Peratherium fugax*. Except for size, the morphology of the present form agrees exactly with that seen in *P. fugax*. On M¹, the metaconule is not well defined. The posterior walls of the protocone and the metacone form a continuous posterior border of the tooth. Styler cusp C is prominent and relatively high. Unlike *P. knighti*, the buccal border of the crown is concave as in *P. fugax*. In relation to this, styler cusp C is situated more lingually in the present form and in *P. fugax* than in *P. knighti*. On M², the metaconule is prominent and expanded posteriorly. The posterior walls of the protocone and the metacone meet at an angle. The buccal border of the styler shelf between styler cusps B and C is concave as in *P. fugax*. On M³, the concavity of the buccal border of the styler shelf is more exaggerated than on M¹ and M². The metaconule is less prominent than on M².

The morphology of lower molars is very similar to that seen in *P. fugax* and *P. knighti*. The buccal cingulum is slightly more prominent than in *P. fugax*, but this character is variable. I cannot find any morphological characters other than size on the lower molars to separate this species from other species of *Peratherium*. On M₃, the paraconid is elongate transversely and the lingual end of it is situated more lingually than in *P. fugax*. Because of this character, the width of M₃ is slightly greater than the corresponding tooth of *P. fugax*. But this character is not always true for all specimens of M₃; some specimens have a normal paraconid. Moreover, this character is seen also in a few specimens of *P. fugax* from the middle Oligocene.

Discussion.—Macdonald (1963) described *P. spindleri* from the lower Miocene of the Wounded Knee Area, South Dakota. The diagnosis of this new species of *Peratherium* given by him (1963:164) is as follows: "of medium size; strongly developed anterior and posterior cingula; labial cingulum continuous." The holotype of *P. spindleri* is significantly smaller than *P. fugax*. The size of the Badwater specimens is intermediate between *P. fugax* and *P. spindleri*. Badwater specimens show a wide range of morphological variation of the development of cingula. On some specimens, the development of cingula is weak so that the anterior cingu-

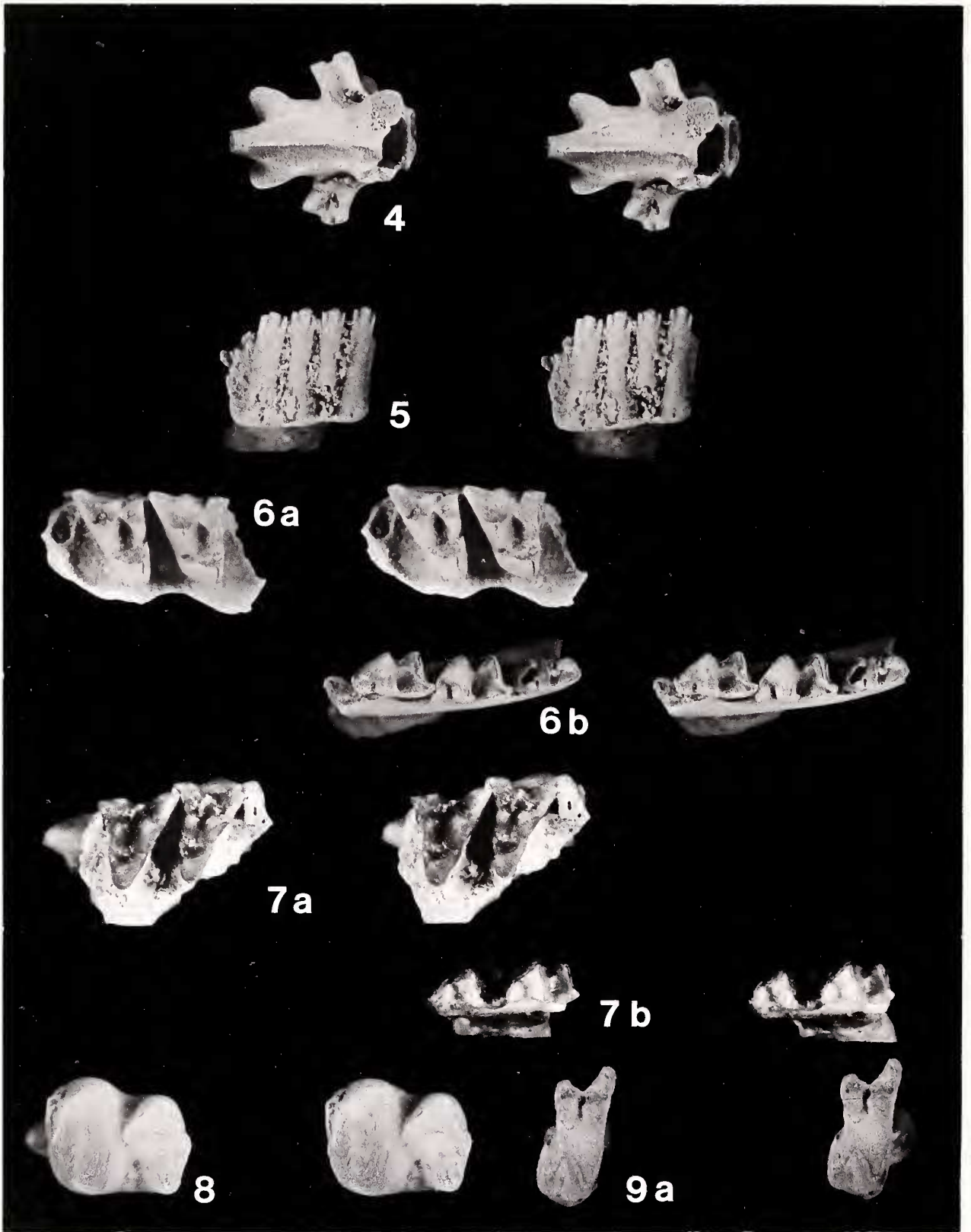


Table 1.—Dimensions of teeth of *Peratherium* sp. cf. *P. spindleri* and unnamed new species of *Nanodelphys*.

Statistics	M ¹		M ²		M ³		M ¹		M ²		M ³	
	L	W	L	W	L	W	L	W	L	W	L	W
<i>Peratherium</i> sp. cf. <i>P. spindleri</i>												
N	36	36	25	25	19	19	20	20	23	23	17	17
OR	1.62– 2.00	1.73– 2.22	1.66– 2.08	1.81– 2.43	1.68– 2.09	2.21– 2.65	1.66– 1.91	0.88– 1.12	1.78– 2.09	1.00– 1.23	1.74– 2.07	0.99– 1.27
Mean	1.788	1.944	1.836	2.098	1.887	2.433	1.798	1.016	1.925	1.119	2.005	1.181
SD	0.1226	0.1279	0.1175	0.1781	0.1133	0.1403	0.0700	0.0691	0.0876	0.0675	0.1004	0.0870
CV	6.86	6.58	6.40	8.49	6.01	5.77	3.89	6.80	4.55	6.03	5.01	7.37
<i>Nanodelphys</i> new species												
N	16	16	17	17	18	18	8	8	25	25	24	24
OR	1.18– 1.46	1.30– 1.77	1.18– 1.52	1.48– 1.77	1.12– 1.32	1.52– 1.74	1.20– 1.64	0.62– 0.81	1.23– 1.53	0.67– 0.90	1.24– 1.47	0.70– 0.87
Mean	1.319	1.444	1.355	1.604	1.243	1.612	1.355	0.735	1.348	0.768	1.375	0.796
SD	0.0620	0.1202	0.0787	0.0910	0.0548	0.0683	0.1496	0.0659	0.0679	0.0537	0.0541	0.0456
CV	4.70	8.33	5.81	5.68	4.41	4.24	11.04	8.97	5.04	7.00	3.94	5.73

lum does not unite with the buccal cingulum. On others, the anterior cingulum continues to run posteriorly along the buccal base of the protoconid and unite with the buccal cingulum. The latter character is also seen in a few specimens of *P. fugax* from the middle Oligocene. I do not agree that the greater development of cingula is a good criterion to separate species of *Peratherium*. Size is the only criterion, which separates *P. spindleri* from *P. fugax*.

Nanodelphys new species (Fig 1., Table 7)

Referred specimens.—M¹-M²: CM 33549, M²-M³ and broken M⁴: CM 33600; M³-M⁴: CM 33601; M¹: CM 33602–33616; M²: CM 33617–33632; M³: CM 33628, CM 33633–33647; M⁴: CM 33648; P₂-P₃: CM 19806; M₂-M₃: CM 19805, CM 33553; M₂-M₄: CM 33554; M₃-M₄: CM 17081, CM 19803, CM 21697; M₁: CM 33545–33552; M₂: CM 19804, CM 33555–33575; M₃: CM 33576–33594; M₄: CM 19802, CM 33595–33598.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Description.—The general morphology of upper molars resembles that of *N. minutus*. The paracone and the metacone are somewhat more appressed anteroposteriorly. The posterior ridge of the paracone and the anterior ridge of the metacone are more sharp and well defined than in *N. minutus*. These two ridges are as strong as the parastylar or metastylar crests in the present form, whereas in *N. minutus* these ridges are clearly weaker than the parastylar and metastylar crests. This condition

indicates that the upper molars of this species of *Nanodelphys* approach the dilambdodont tooth pattern.

In the lower molars, the postcristid and the hypoconulid block the talonid basin posteriorly. The crista obliqua is straight, not concave as in *N. minutus* and the hypoflexid does not excavate the talonid basin buccally as in *N. minutus*. The hypoconulid is displaced more lingually than in *N. minutus* and situated posterior to the entoconid. The postcristid is almost transverse and forms an acute ridge. The hypoconulid is lower than the entoconid but still higher than the talonid basin. The posterior cingulum is very weak and terminates lingually at the base of the hypoconulid. The posterior cingulum does not unite with the occlusal surface of the hypoconulid.

Discussion.—Upper molars of the present form approach the dilambdodont condition. *Nanodelphys minutus* has upper molars with less well-developed dilambdodont tooth pattern, as I discussed elsewhere (Setoguchi, 1975). In animals with dilambdodont upper teeth, the lower molars have a hypoconid with a very sharp buccal angle that occludes with the ectoloph of the upper teeth. These teeth either lack a hypoconulid or have this cusp displaced (Robinson, 1968). In *Nanodelphys minutus* the displacement of the hypoconulid is less emphasized in the lower dentition. The hypoconulid is situated posterobuccal to the entoconid in *N. minutus*. In the present form, the displacement of the hypoconulid is emphasized; this cusp is situated posterior to the entoconid. This condition is very

Fig. 4.—? *Batrachosauroides* sp. CM 33649, vertebra. ×8. Fig. 5.—*Leiocephalus* sp. CM 33650, jaw with teeth. ×10. Fig. 6.—*Peratherium* sp. cf. *P. spindleri*. a: CM 33439, left M²-M³. b: CM 33481, right M₂-M₃. ×8. Fig. 7.—*Nanodelphys* new species, unnamed. a: CM 33600, left M²-M³. b: CM 19805, right M₂-M₃. ×10. Fig. 8.—*Leptictis* sp. CM 21676, right M₂. ×8. Fig. 9a.—*Ankyledon* sp. cf. *A. annectens*. CM 33658, right M². ×8.

Table 2.—Dimensions of teeth of *Leptictis* sp. and *Ankylodon* sp. cf. *A. annectens*.

Statistics	M ¹			M ²			P ₄		M ₁			M ₃		
	L	AW	PW	L	AW	PW	L	W	L	AW	PW	L	AW	PW
<i>Leptictis</i> sp.														
N				1	1	1								
OR				3.46	2.77	2.34								
<i>Ankylodon</i> sp. cf. <i>A. annectens</i>														
N	1	1	2	1		1	2	2	2	2		1	1	1
OR	1.72	3.11	2.57– 2.66	0.98		2.08	1.76– 1.77	1.26– 1.32	1.74– 1.85	1.53– 1.66	1.47– 1.65	1.87	1.57	1.29

similar to the talonid structure of *Peratherium*. But in the lower dentition of *Peratherium*, the hypoconulid forms a horizontal, posteriorly directed ledge directly posterior to the entoconid, and the talonid basin opens posteriorly across the flattened hypoconulid. Moreover, in *Peratherium*, the posterior cingulum is well developed; this cingulum unites lingually to the buccal face of the hypoconulid so that the hypoconulid and the posterior cingulum are a continuous structure. On the other hand, in the present form of *Nanodelphys*, the hypoconulid and the postcrisid block the talonid basin posteriorly, and the posterior cingulum does not form a continuous structure with the hypoconulid.

Dr. Larry D. Martin at the University of Kansas (personal communication) informed me that he has several specimens of *Nanodelphys* from the lower Miocene Gering Formation, Nebraska, that are not separable from the present form at the specific level. He has better specimens and he will give the diagnosis of the new species so that I leave the new species unnamed.

Infraclass Eutheria
Order Insectivora
Family Leptictidae Gill, 1872
Leptictis sp.
(Fig. 8, Table 2)

Referred specimens.—M₂: CM 21676.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—The trigonid is wider transversely than the talonid. The specimen available is worn. Apparently, the paraconid is reduced to crest-like shape and it gives the tooth a more quadrate outline in occlusal view. The apices of the protoconid and metaconid are nearly opposite each other. The hypoconid is stout and the crista obliqua joins to the posterior wall of the trigonid a little buccal to the midpoint of it. The entoconid is small and is situated a little posterior to the hypoconid. Between

the metaconid and the entoconid a wide and deep valley opens lingually. On the lingual margin of the floor of the valley, a small cusplule is present.

Discussion.—Only one specimen referable to *Leptictis* is available in the present fauna. *Leptictis* (= *Ictops*) is the most varied and individually the most abundant genus of the family in the White River Oligocene (Scott and Jepsen, 1936:13). *Leptictis* in the present fauna is the youngest occurrence of the genus. But, it is difficult to give the specific identification for this material because the only specimen available is worn.

Family Adapisoricidae (Schlosser, 1887)
Ankylodon sp. cf. *A. annectens* Patterson and
McGrew, 1937
(Fig. 9, Table 2)

Referred specimens.—M¹: CM 21675; M²: CM 17095, CM 33651, CM 33652, CM 33653; M³: CM 21699; P₄: CM 33654, CM 33655; M₁: CM 33656, CM 33657; M₂: CM 33658; M₃: CM 33659.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—Material referable to *Ankylodon* is known from the late Eocene to the middle Oligocene. The late Eocene *Ankylodon* is known only from a single M¹, a single M₂, and some fragmentary materials (Krishtalka and Setoguchi, 1975). An excellent, nearly complete palate with complete jaws of both sides is known from the Chadronian. *Ankylodon annectens* (including *A. progressus*; see Krishtalka and Setoguchi, 1975) is known only from the lower dentition.

Like the Chadronian *Ankylodon*, M² of the present form is transverse and has a strong hypocone. The paracone is tall and transverse. The metacone is reduced in size and in height when compared with the Chadronian species. The postmetacrista and the metastylar area are also weaker than in the Chadronian form. In relation to these, the posterior wing of the metaconule terminates nearly at the posterior base of the metacone, whereas in the Chadronian specimen the posterior metaconule wing extends along the posterior base of the metacone and joins the posterolingual base of the postmetacrista. The parastylar area expands buccally but it is narrower anteroposteriorly than in the

Table 3.—Dimensions of teeth of *Centetodon* sp. cf. *C. marginalis* and *Domnina* sp. cf. *D. gradata*.

Sta- tistics	P ¹		M ¹			M ²			P ₄		M ₁			M ₂			M ₃		
	L	W	L	AW	PW	L	AW	PW	L	W	L	AW	PW	L	AW	PW	L	AW	PW
<i>Centetodon</i> sp. cf. <i>C. marginalis</i>																			
N	1	1		1		1	1	1	2	2				1	1	1	2	2	2
OR	1.69	2.18	—	2.22	—	1.38	2.47	2.27	1.55– 1.64	0.88– 1.01				1.86	1.21	1.13	1.54– 1.66	0.98– 1.06	0.80– 0.81
<i>Domnina</i> sp. cf. <i>D. gradata</i>																			
N	2	2	3	3	3	3	3	3			4	4	4	2	2	2	2	2	2
OR	1.97– 1.99	1.98– 2.00	1.99– 2.08	2.05– 2.17	2.15– 2.22	1.89– 1.97	2.04– 2.07	1.80– 1.92			2.12– 2.20	1.21– 1.47	1.31– 1.58	1.81– 1.96	1.14– 1.38	1.16– 1.42	1.49– 1.52	0.94– 0.96	0.80– 0.85
Mean			2.043	2.097	2.193	1.920	2.057	1.860			2.170	1.353	1.490						

Chadronian form. In this regard the styler shelf area is narrower anteroposteriorly than the Chadronian species.

CM 21699 is identified as M³. The metacone is the only prominent cusp. It is conical and is situated on the middle of the buccal half of the crown. The parastyle area expands anterobuccally but the preparacrista is represented by a weak ridge on the anterobuccal face of the paracone. The styler shelf is truncated and narrow posteriorly. The metacone is greatly reduced. The protocone forms a triangle with the acute angle lingually. The hypocone is greatly reduced and represented by an enamel crenulation.

P₄ is molariform. It is basically similar in construction with its homologue in *Geolabis*, but is proportionately much shorter and broader. In the Chadronian species of *Ankyledon*, the paraconid is a forward-leaning, short transverse ridge, but it is still a well-defined cusp. In the present form, the paraconid is not a distinct cusp but just an anterior continuation of the anterolingual ridge of the protoconid, which lingually slopes sharply ventrad. The protoconid is taller than the metaconid. The metaconid is elongated lingually so that the protoconid and the metaconid are more widely separated from each other than in the Chadronian species and the Orellan *Ankyledon annectens*. A short weak anterior cingulum is present on the anterior face of the protoconid. The talonid structure agrees exactly with that of the Chadronian species and the Orellan *A. annectens*.

On M₁, the trigonid is a little narrower transversely than the talonid as in the Orellan *A. annectens*, whereas the former is clearly narrower than the latter in the Chadronian form. No cingula are present at all. The metaconid is taller than the protoconid as in the other forms of *Ankyledon*. The talonid is shorter than that in the Orellan *A. annectens* and more so than the Chadronian form. No trace of the hypoconulid is present whereas a rudimentary hypoconulid is clearly present in the Chadronian and the Orellan forms. The entoconid is taller than the hypoconid as in the other forms of *Ankyledon*, but the difference in height between the metaconid and the entoconid is more exaggerated in the present form than in the Orellan form and more so than in the Chadronian form. The notch between the metaconid and the entoconid is deeper than in any other forms of *Ankyledon*.

CM33658 is identified as M₂ because the trigonid is slightly wider transversely than the talonid. No cingula are present. The talonid is narrower anteroposteriorly than in the other members of this genus, and the crista obliqua is concave. No trace of the hypoconulid is seen, whereas in the late Eocene form there is

a distinct hypoconulid. The notch between the metaconid and the entoconid is also deep, whereas in the late Eocene species the entocristid joins these two cusps and closes the talonid basin lingually.

On M₃, the talonid is narrower transversely than the trigonid. The hypoconulid is present although rudimentary.

Discussion.—The present form is clearly different from the Chadronian species in having a more reduced parastyle and narrower styler area on the upper molars, more reduced paraconid, no cingulum, deeply separated metaconid and entoconid with the former clearly taller than the latter, and transversely narrower talonid. In these respects, the Orellan *Ankyledon annectens* is intermediate between these two forms. The differences between the present form and the Chadronian species cited above are more clearly exaggerated if my material is compared with the late Eocene form. The present material is more advanced or specialized than either the late Eocene or the Chadronian species. But the distinguishing features listed above, or the morphological differences between the present form and the Orellan *A. annectens*, seem minor and possibly are within the range of usual variation within a species.

Family Geolabididae (McKenna, 1960)

Centetodon sp. cf. *C. marginalis* (Cope, 1874) (Fig. 10, Table 3)

Referred specimens.—P⁴: KU 16606; M¹: CM 33661; M²: CM 33662; P₃: CM 21673; P₄-M₂: CM 33663; P₄: CM 21674, CM 33664; M₂-M₃: CM 21672, M₃: CM 33665, CM 33666.

Locality.—Loc. 19, Badwater Creek Wyoming.

Age.—Late Oligocene.

Description.—The structure of P¹ closely resembles that in *Centetodon marginalis* and *C. chadronensis* (Lillegraven and McKenna, manuscript). A small anterior lingual cingulum is present on the anterolingual base of the protocone. The width

of this cingulum is almost half that of posterior cingulum. The anterior lingual cingulum is not present on the Chadronian *Centetodon chadronensis*, but on *C. marginalis* a small anterior cingulum is present on the base of the anterior face of the protocone. It is widely separated from the posterior cingulum. On the present form, the anterior lingual cingulum is shifted more lingually and almost united with the posterior cingulum along the base of the lingual face of the protoconid. In this connection, the lingual base of the crown of P⁴ is wider anteroposteriorly than in *Centetodon chadronensis* and *C. marginalis*. The posterior cingulum has a slight elevation on the posterolingual base of the protocone and a low, small cingulum runs anteriorly along the lingual base of the protocone. That elevation is more buccal on *C. marginalis* and directly posterior to the protocone on *C. chadronensis*. The lingual root is not bifurcated on the material at hand.

Distinctions in the upper molars between *Centetodon marginalis* and my specimens are minor. A tendency toward a deeper labial emargination of the styler shelf on M² is observed in this form, but the general morphology is essentially the same as in *C. marginalis*.

P⁴ is a large semimolariform tooth and its structure is exactly the same as the corresponding tooth of *Centetodon marginalis*. Moreover, there are no really obvious morphological differences on lower molars between *C. marginalis* and the present specimens). The mental foramen is below the posterior root of P₃.

Discussion.—The general morphology of my material is essentially the same as that of *Centetodon marginalis*. The only obvious difference is in the degree of the development of the anterior lingual cingulum on P⁴. The anterior lingual cingulum is more developed in the present form than in *C. marginalis*. Lillegraven and McKenna (Manuscript) clearly describe the evolutionary sequence of *Centetodon chadronensis*–*C. marginalis*. In *C. chadronensis* there is no anterior cingulum on P⁴, but a small anterior cingulum is usually present on the base of the anterior face of the protocone in *C. marginalis*. Even in the latter form, the anterior cingulum is widely separated from the posterior cingulum at the lingual margin of the protoconid. In the present form, the anterior cingulum is shifted more lingually and closer to the posterior cingulum. This is just a continuation of the sequence toward better development of the anterior cingulum on P⁴ in the *Centetodon chadronensis*–*C. marginalis* lineage. The present form is surely in this lineage and is descended from the Orellan *C. marginalis*.

A new species of *Centetodon terminalis* will be described by Lillegraven and McKenna (manuscript). The materials referred to the new species were originally discussed by Martin (1972) from the lower Miocene Gering Formation of Nebraska. This form is known only from P₄ and M₁. Morphologically, however, it shows no obvious differences from homologous teeth of *C. marginalis* except for their size. The size of the tooth suggests an animal significantly larger than *Centetodon marginalis* yet smaller than *C. wolffi*. The trends in proportional changes seen in the transition from *C. chadronensis* to *C. marginalis* seem to continue into *C. germinalis*. The size of the present form, which is intermediate between *C. marginalis* and *C. terminalis*, supports this hypothesis.

Family Soricidae (Fischer von Waldheim, 1817)

Domnina sp. cf. *D. gradata* Cope, 1873

(Fig. 11, Table 3)

Referred specimens:—P⁴-M¹: CM 33667; CM 21662, CM 33668, CM 33669; M¹: CM 21663, DM 33670, DM 33671, DM 33672; M²: CM 33673, CM 33674, CM 33675, CM 33676, CM 33677; P₁-P₃, M₁: CM 33678; M₁-M₃: CM 33679; M₁: CM 21664, CM 33680, CM 33681, CM 33682, CM 33683, CM 33684; M₂-M₃: CM 33685; M₂: CM 21665, CM 33686; M₃: CM 33687.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—P⁴ has a tall paracone that tapers posterobuccally to the metastylar tip of the crown. The anterior wall of the paracone is very steep as in the other species of *Domnina*. A low parastyle runs anteriorly from the base of the paracone. The protocone is weak. The hypoconal shelf expands posteriorly, unlike the condition in *Trimylus*.

M¹ lacks an emargination of the posterior border of the crown and the hypoconal shelf expands posteriorly. Accordingly, the crown is quadrate in occlusal view; rather longer than wide, whereas in *Trimylus* M¹ is wider than long. M² approaches M¹ in general morphology except for a wider paracone and smaller hypocone. M² lacks an emargination of the posterior border of the crown.

P₁ is longer and wider than either P₂ or P₃. Lower molars have a high entocristid, which joins the entoconid to the posterior face of the metaconid and closes the talonid basin lingually. On M₁, the anterior cingulum runs along the anterior base of the paraconid and along the anterobuccal base of the protoconid. The buccal cingulum runs posteriorly from the buccal base of

→

Fig. 9b-e.—*Ankylodon* sp. cf. *A. annectens* (continued). b: CM 21699, left M³. c: CM 33654, left P₄. d: CM 33658, right M₂. e: CM 33659, left M₃. ×8. Fig. 10.—*Centetodon* sp. cf. *C. marginalis*. a: KU 16606, left P⁴, ×8. b: CM 33662, right M², ×8. c: CM 33663, left P₁-M₂, ×10. d: CM 21672, left M₂-M₃, ×10. Fig. 11.—*Domnina* sp. cf. *D. gradata*. a: CM 33667, left P⁴-M¹. b: CM 33673, left M². c: CM 33678, left P₁-P₃, M₁. d: CM 33685, left M₂-M₃. ×8. Fig. 12.—*Proscalops miocaenus*. a: CM 33688, left M¹. b: CM 33690, left M². c: CM 33694, left M₁. d: CM 33696, left M₂. ×8.

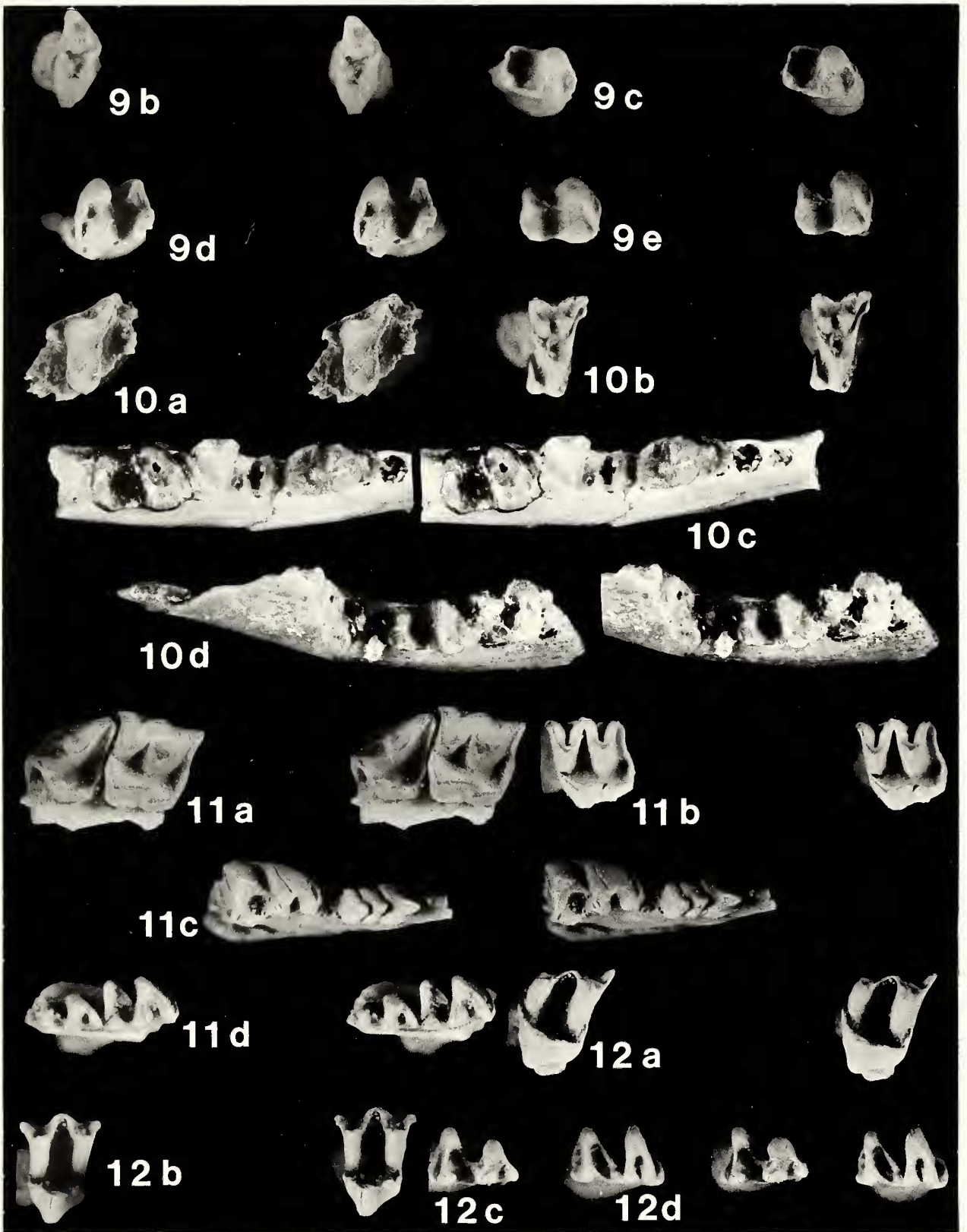


Table 4.—Dimensions of teeth of *Proscalops miocaenus*, *Oligoscalops* ? sp., and *Micropternodus* sp.

Statistics	M ¹			M ²			M ³			M ₁			M ₂			M ₃		
	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW
<i>Proscalops miocaenus</i>																		
N	2	2	2	2	2		1	1		4	4	4	1	1	1			
OR	2.02– 2.37	1.99– 2.05	2.67– 2.78	1.76– 1.96	2.31*– 2.53*		1.41	1.77	—	1.79– 1.905	1.02– 1.075	1.34– 1.405	2.18	1.41	1.30			
<i>Oligoscalops</i> ? sp.																		
N													1	1	1			
OR													1.62	1.17	1.03			
<i>Micropternodus</i> sp.																		
N																		1
OR																		— 1.23 —

* Width at the mesostyle.

the protoconid. On five of the six M₁s, the anterior cingulum does not unite with the buccal cingulum although they are very close together. On one specimen, these cingula are united along the buccal base of the protoconid, although the cingula are very weak there. The labial cingulum is very weak along the buccal base of the hypoconid.

The mental foramen is below the middle of M₁.

Discussion.—Patterson and McGrew (1937) and Repenning (1967) have thoroughly described *Domnina gradata* from the Orellan of Colorado, South Dakota, and Nebraska. In the absence of preserved mandibular condyles or the antemolar dentition, *Domnina*, as well as all other heterosoricines, is best defined by P⁴ and M¹ that lack an emargination of the posterior border of the crown and the resultant posterior expansion of the hypoconal shelf. Instead, the posterior margin of P⁴ and M¹ of *Domnina* is nearly straight or expands a little posteriorly and the crown is longer than wide, especially on M¹. In relation to the non-bulbous feature of P₄ and M₁ in *Domnina* (in *Trimylus*, lower molars are bulbous), P⁴ has a tall paracone and the anterior wall of the cusp is very steep, whereas that in *Trimylus* forms a more gentle slope. Such is the case for P⁴ and M¹ in this sample.

The lower molars referred here are very similar to those of *Domnina* and differ from those of *Trimylus* in that a high crest joins the entoconid to the posterior face of the metaconid and closes the talonid basin lingually. In *Trimylus* a deep notch isolates the entoconid from the metaconid (Repenning, 1967). The anterior cingulum anterobuccal to the protoconid on M₁ is a little more developed than in the Orellan *Domnina gradata*. In the latter form,

the buccal cingulum on M₁ is not continuous around the base of the protoconid. In the present form, this feature of the cingula approaches being continuous around the base of the protoconid.

The early Miocene *D. greeni* is not well known. In the original description, Macdonald stated (1963:168), "Labial cingulum on anterior labial face of trigonid only." In the present form, the buccal cingulum buccal to the hypoconid is reduced. The present form may have given rise to *D. greeni*.

Family Talpidae Gray, 1825
***Proscalops miocaenus* Matthew, 1901**
(Fig. 12, Table 4)

Referred specimens.—M¹: CM 33688, CM 33689; M²: CM 33690, CM 33691; M³: CM 33692; M₁: CM 21668, CM 33693, CM 33694, CM 33695; M₂: CM 33696.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Description.—The size of the teeth is close to that of the holotype of *Proscalops miocaenus*. On M¹, the protocone is V-shaped with an apex which is oriented anterolingually. The anterior arm of the protocone runs anterobuccally and soon turns buccally. It continues to run along the anterior face of the paracone and connects to the parastyle. The anterior face of the anterior protocone arm has a small anterior projection at the midpoint between the protocone and the paracone. This small projection is what Reed called the protostyle (Reed, 1961:487). A small, but distinct hypcone is present posterior to the protocone. Thus, the lingual portion of the tooth is somewhat broader. The paracone is smaller than the metacone. The former is blade-like running rather posterobuccally, whereas the latter is V-shaped. The posterior arm of the metacone is longer than the anterior arm. The former extends posterobuccally and connects to the metastyle which forms the posterobuccal corner of the crown. Thus, the buccal portion of the crown is truncated an-

teriorly so that the anterior portion is narrower transversely than the posterior one. A small mesostyle is present near the midline on the buccal border of the crown.

On M^2 , the anterior arm of the protocone terminates at the base of the anterior face of the paracone. It does not extend buccally beyond the point of the apex of the paracone so that it appears to be shorter anteroposteriorly. As in M^1 a small "protostyle" is present on the anterior arm of the protocone, and a small hypocone is also present posterior to the protocone. The protocone is more acutely V-shaped than in M^1 , and the apex is oriented more mesially. The paracone and the metacone are subequal, forming acute V's. The parastyle and the metastyle are also subequal. A robust mesostyle lies on the middle of the buccal border of the crown. Thus, the buccal part of the crown is symmetrical.

M^3 is reduced. The general morphology agrees with that of M^2 although M^3 is smaller than M^2 . The portion posterobuccal to the anterior arm of the metacone is completely truncated so that the posterior arm of the metacone and the metastyle are not present. The mesostyle is also reduced in size. The paracone is wider buccally than in M^1 .

On M_1 , the trigonid is narrower transversely than the talonid. The protoconid is the tallest of the cusps on the trigonid. The protoconid is elongated transversely and forms a V with the apex buccal. The paraconid is the lowest of the trigonid cusps and is situated anterior to the anterior face of the protoconid. The metaconid is situated posterior to the posterior face of the protoconid. Thus, the lingual side of the trigonid is wide anteroposteriorly while the protoconid itself is compressed anteroposteriorly. A rudimentary anterior cingulum is present on the anterobuccal base of the paraconid. The hypoconid is elongated transversely. The crista obliqua extends anterolingually and connects to the posterobuccal corner of the metaconid. The buccal face of the crista obliqua is very steep and the hypoflexid is very deep. The median cingulum is not present between the protoconid and the hypoconid, as in *Mesoscalops*. The entoconid is conical. A transverse ridge unites the hypoconid and entoconid. No entocristid is present between the entoconid and the metaconid so that the talonid basin opens lingually. A rather well-developed posterior cingulum is present on the posterior base of the talonid.

CM 33969 is identified as M_2 of this species. The trigonid is a little wider transversely than the talonid. The lingual part of the trigonid is narrower anteroposteriorly than in M_1 . The protoconid is also compressed anteroposteriorly as in M_1 , but the paraconid is merely a lingual extension of the anterior arm of the protoconid. The anterior cingulum is wide lingually and descends buccally to the base of the anterior face of the protoconid. The metaconid is elongated anteroposteriorly and has a small notch on its buccal face. The almost transverse posterior arm of the protoconid connects to the midpoint of the elongated metaconid, forming an anterior wall with a notch on the buccal face of the metaconid. The hypoconid is compressed anteroposteriorly. The crista obliqua reaches to the posterobuccal corner of the metaconid, posterior to the notch of the metaconid mentioned above. Thus, the crista obliqua does not connect to the trigonid proper but to the posterior extension of the metaconid. The remainder of the features are almost identical to those of M_1 .

Discussion.—The lower molars of the present form do not have a median cingulum between the

protoconid and the hypoconid, as do those of *Mesoscalops*. *Oligoscalops* is best defined by P^4 that has a large parastylar area, whereas the corresponding tooth of *Proscalops* lacks a parastylar area. In the present fauna, no materials referable to P^4 are available. In her original description of *Oligoscalops*, Reed stated (Reed, 1961:486–487), " M^1 in *Oligoscalops* is triangular in general outline, with the protocone directed anteriorly. The hypocone is rudimentary, a mere protuberance labial and posterior to the protocone In *Proscalops miocaenus* the tooth is generally similar, although the hypocone is somewhat better developed and the lingual portion of the tooth therefore somewhat broader. A rudimentary protostyle is present." M^1 of the present form has the small "protostyle," better developed hypocone, and the broader lingual portion of the crown. This form does not belong within the genus *Oligoscalops*. According to Reed (Reed, 1961:487), in *Proscalops tertius* and *P. secundus*, the hypocone is better developed on M^1 than in *P. miocaenus*. The degree of development of the hypocone on M^1 of the present form is close to that in *P. miocaenus*.

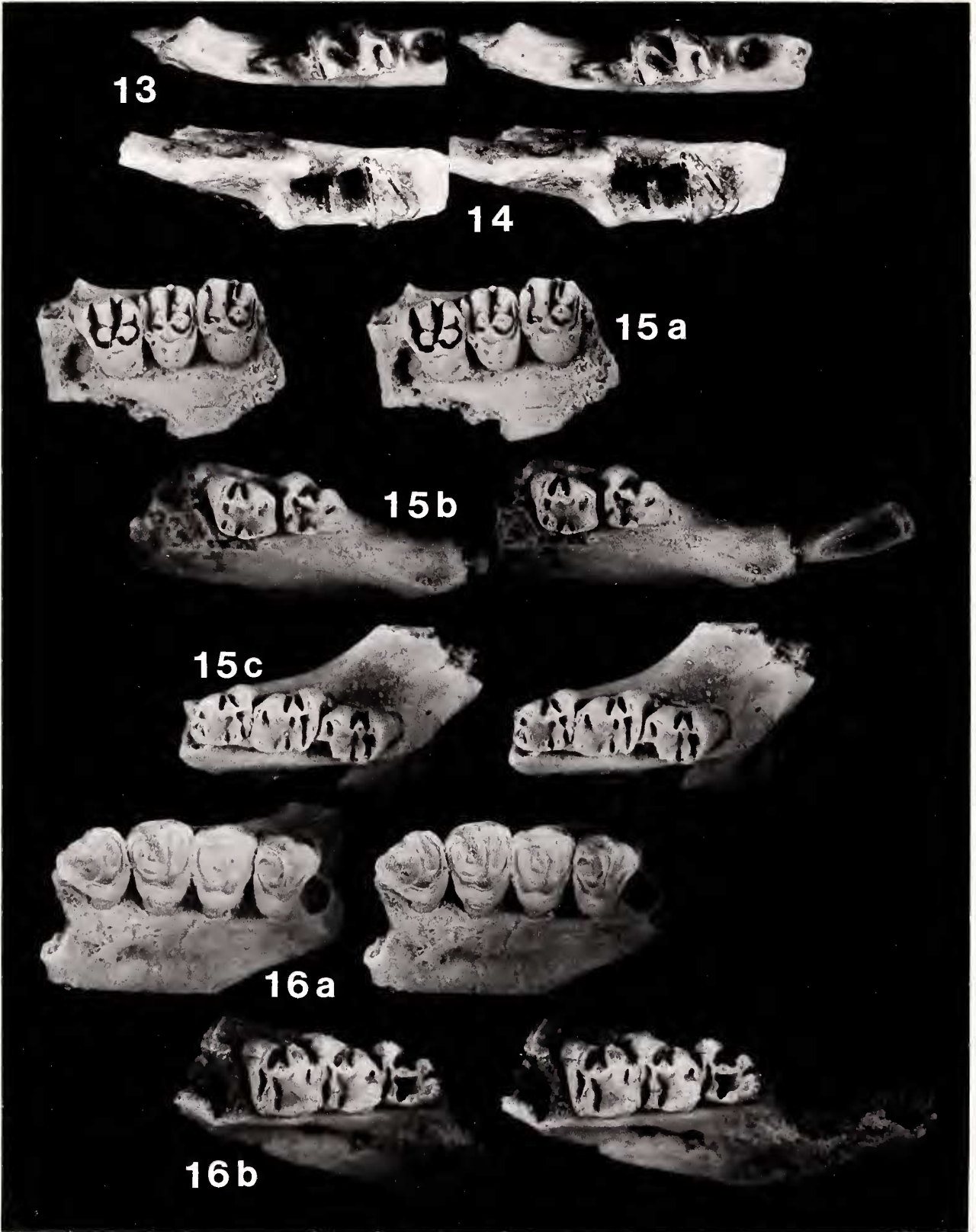
***Oligoscalops* ? sp.** (Fig. 13, Table 4)

Referred specimen.—CM 17441, a left ramus with M_2 .

Locality.—Loc. 19, Badwater Creek Wyoming.

Age.—Late Oligocene.

Description.— M_2 is small. The size of the tooth is smaller than that of *Proscalops miocaenus*. The trigonid is narrow anteroposteriorly. The protoconid is elongated transversely and the paraconid forms a transverse ridge at a slightly worn stage. The paraconid does not reach to the lingual extremity of the base of the trigonid, leaving a shelf lingual to it. On this specimen, the metaconid is broken and only the base of it remains. The base of the metaconid is longer transversely than that of the paraconid reaching the lingual border of the trigonid. A rather broad anterior cingulum is present at the base of the anterior face of the trigonid, and the lingual extension of the cingulum surrounds the anterolingual base of the paraconid and continues to run posteriorly to connect to the anterolingual base of the metaconid. The talonid is a little narrower than the trigonid. The hypoconid is compressed anteroposteriorly. The crista obliqua runs anterolingually and connects to the trigonid at a point one-third of the way from the lingual side on the posterior wall of the trigonid. The hypoflexid is deep. The entoconid is conical and situated on the posterolingual corner of the tooth. A transverse ridge unites the posterior corners of the hypoconid and the entoconid. A small anteroposteriorly elongated metastylid is situated on the lingual border between the metaconid and the entoconid. The metastylid completely blocks the talonid basin lingually. The hypoconulid is very low, situated just posterior to the entoconid. The posterior cingulum is rudimentary.



Discussion.—*Oligoscalops* is smaller than *Proscalops miocaenus*. *Oligoscalops* was established by Reed (1961), and a new species *O. whitmanensis* was regarded as the smallest known member of the Proscalopinae. She gave the diagnosis for the upper dentition of this new form but did not describe the morphology of the lower dentition. The holotype is CM P 25800, partial skull and jaws, but a lower jaw with P₂-M₃, KU 8143 is included in the hypodigm by her. In her discussion, she stated (Reed, 1961:488), "(In the Kansas specimen) In M₁ the talonid is wider than the trigonid, judging from the fragments that remain, and the opposite is true of M₂." In the measurements of the new form, she gave the trigonid and talonid width of M₂ of the Kansas specimen as 1.7 and 2.1 mm, respectively. According to the measurements given by her, the talonid is wider than the trigonid.

Family Micropternodontidae Stirton and
Rensberger, 1964
Micropternodus sp.
(Fig. 14, Table 4)

Referred specimen.—Mandible with M₃.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description and discussion.—Only one lower jaw with M₃ and the posterior part of the ramus is available. On M₃, the tip of the paraconid and the lingual half of the talonid are broken off. The tooth is somewhat worn. The trigonid is transverse and compressed anteroposteriorly. The metaconid is taller than the protoconid. The protoconid is acutely V-shaped with its apex buccally. The anterior cingulum is developed along the anterior base of the trigonid. This cingulum is narrower buccally, terminates at a point anterior to the protoconid, and does not reach to the buccal face of this cusp. Lingually, the anterior cingulum becomes broader and its lingual extremity reaches to the lingual base of the paraconid. Thus, the cingulum surrounds the anterolingual base of the paraconid. The hypoconid is also V-shaped with its apex buccal. The hypoconid is lower than the protoconid. The crista obliqua does not connect to the protoconid nor to the

protolophid; instead, it runs directly anterolingually to connect to the metaconid. This characteristic feature is also seen in M₃ referable to *Micropternodus borealis* where the hypoconid is connected to the metaconid by a crest (Russell, 1960:945). Because of the lingually extended crista obliqua, the hypoflexid is long transversely. The hypoflexid slopes down buccally. Because the lingual portion of the talonid is broken, it is impossible to tell whether or not the hypoconulid is present on M₃.

The coronoid process of the mandible is rather slender. The anterior face of the coronoid process is almost perpendicular to the occlusal plane or leans somewhat anteriorly.

The present form is identified as *Micropternodus* sp. because of the similarity of the talonid structure to that of *M. borealis* of the early Oligocene. The present sample is not sufficient to warrant specific identification.

Order Rodentia
Family Aplodontidae Trouessart, 1897
Prosciurus relictus (Cope, 1873)
(Fig. 15, Table 5)

Referred specimens.—P³-M¹: CM 33262, P³-M³: CM 33261; P⁴-M¹: CM 19714, CM 33266; P⁴-M²: CM 33263-33265; P⁴-M³: CM 17078; P³: CM 33276; DP⁴: CM 33268-33275; P¹: CM 17405, CM 17408, CM 17410, CM 33277-33305; M¹-M²: CM 33267; M¹ or M²: CM 17406, CM 19793, CM 33306-33379; M³: CM 17089, CM 17094, CM 33380-33403; P₄-M₁: CM 19791, CM 33122-33124; P₄-M₃: CM 33121; DP₄: CM 33133-33137; P₄: CM 17076, CM 17409, CM 33138-33158; M₁-M₃: CM 33125-33128; M₂-M₃: CM 33129-33132; M₁ or M₂: CM 17403, CM 33159-33220; M₃: CM 17077, CM 17404, CM 19794, CM 33221-33260.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—P³ is peglike. The apex of the cusp is shifted slightly anteriorly and a small ridge descends posteriorly from the apex.

DP⁴ is identified on the basis of its tiny size and the similar tooth structure to that of P⁴ referable to this species. In both the parastylar lobe extends anterobuccally and a small, but distinct, cusp is formed on its anterior border. This cusp is lower than the protoconule. The cusp lies lingual to the metacone-paracone line and the distance between the parastylar cusp and the paracone is nearly the same as that between the paracone and the metacone. The transverse valley between the parastylar cusp and the protoloph opens more widely in DP⁴ than in P⁴. The

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Fig. 13.—*Oligoscalops* ? sp. CM 17441, left M₃. ×10. Fig. 14.—*Micropternodus* sp. CM 17442, left M₃. ×10. Fig. 15.—*Prosciurus relictus*. a: CM 33263, left P⁴-M². b: CM 19791, left P₄-M₁. c: CM 33126, right M₁-M₃. ×7. Fig. 16.—*Pelycomys placidus*. a: CM 33101, right P⁴-M³. b: CM 19792, left P₄-M₂. ×5.

Table 5.—Dimensions of teeth of *Prosciurus relictus*.

Statistics	DP ¹		P ¹		M ¹		M ²		M ¹ or M ²	
	L	W	L	W	L	W	L	W	L	W
N	8	8	25	25	7	7	6	6	43	43
OR	1.48– 1.66	1.42– 1.73	1.36– 1.95	1.63– 2.30	1.39– 1.62	1.91– 2.17	1.44– 1.69	1.82– 2.14	1.33– 1.83	1.64– 2.32
Mean	1.554	1.623	1.728	1.943	1.543	2.021	1.567	1.982	1.610	2.000
SD	0.061	0.096	0.150	0.219	0.088	0.111	0.116	0.135	0.114	0.154
CV	3.29	5.92	8.70	11.28	5.72	5.47	7.41	6.83	7.06	7.70

	DP ₄			P ₄			M ₁			M ₂			M ₁ or M ₂		
	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW
N	5	5	5	20	19	20	7	6	7	7	7	7	47	47	47
OR	1.38– 1.54	0.85– 0.98	1.31– 1.48	1.33– 1.91	0.88– 1.49	1.30– 1.97	1.50– 1.83	1.36– 1.61	1.54– 1.80	1.63– 1.97	1.46– 1.80	1.60– 1.95	1.38– 1.94	1.25– 1.74	1.50– 2.07
Mean	1.464	0.914	1.370	1.631	1.186	1.638	1.703	1.480	1.697	1.794	1.624	1.796	1.739	1.514	1.740
SD	0.074	0.054	0.076	0.162	0.165	0.157	0.116	0.097	0.102	0.151	0.132	0.143	0.117	0.118	0.129
CV	5.08	5.92	5.56	9.94	13.88	9.57	6.84	6.58	6.03	8.43	8.14	7.95	6.73	7.77	7.41

floor of the lingual half of the valley is much lower than that between the protoloph and the metaloph. A short ridge descends posterolingual from the parastylar cusp but no connecting ridge is seen between the parastylar cusp and the protocone so that the valley anterior to the protoloph opens lingually unlike P¹. The structure of the protocone is similar to that of P¹. The protoconule is smaller and lower than the metaconule, and both of them are smaller and lower than the subequal paracone and metacone. The protoloph is low in position and extends almost transversely, and the protoconule is formed on its anterior face between the protocone and the paracone. The paracone is elongated transversely. The metaloph is also low in position and extends posterobuccally so that the valley between the protoloph and the metaloph becomes wider buccally. This valley is rather wide and U-shaped, not V-shaped as in P¹. The metaconule is formed on the posterior face of the metaloph. Both the protoconule and the metaconule are connected to the protocone by weak ridges. No hypocone is formed and the posterior cingulum is weak. The tooth is three rooted; the root underneath the protocone is the largest. This root is elongated transversely and its buccal margin reaches to the protoconule-metaconule line. The root extends slightly lingually. Two roots are on the buccal base of the tooth. The anterior root is larger and occupies the bases of the parastylar lobe and the anterior half of the paracone. This root is elongated anteroposteriorly and extends anterobuccally. This third root is just underneath the metacone and extends slightly buccally. The cross section of the root is rounded. These three roots are not close together but open widely. This is another reason why these teeth are identified as DP¹.

P¹ and molar structures are almost the same as those described by Galbreath (1953). On all cheek teeth, a single metaconule is present.

The lower jaw is relatively longer than that of *Pelycomys*. The anterior face of the incisor is flat rather than rounded as in *Pelycomys* and the external face is flat as well. The posterior face is rounded and narrow so that the tooth is narrower posteriorly.

DP₄ is also identified on the basis of its tiny size, its similarity

to P₄, and widely open roots. The protoconid is lower than the metaconid but is wider anteroposteriorly. Both metalophis I and II are complete although they are low in position, and block the trigonid basin anteriorly and posteriorly. The mesoconid is distinct and as high as the entoconid. The ectolophid is not conspicuous but forms an acute edge between the talonid basin and the valley between the protoconid and the hypoconid. No mesolophid is seen. The hypoconid is at the posterobuccal corner of the tooth and is greatly compressed anteroposteriorly; the anterior face is vertical. The hypoconid is separated from the posterolophid by a deep notch. The posterolophid is a tall, transverse blade high above the bottom of the talonid basin. The entoconid is separated from the posterolophid by a small notch. The hypolophid runs buccally from the entoconid and soon turns posteriorly to unite to the anterior face of the posterolophid. The hypolophid does not extend to the ectolophid. The hypolophid, entoconid, and posterolophid share a common base, which raises high above the bottom of the talonid basin. The mesostylid is inconspicuous, and between it and the entoconid is a deep notch, which runs transversely from the talonid basin. The metastylid crest is not present.

The other cheek teeth are very close to those described by Wood (1937) and discussed by Galbreath (1953).

Discussion.—The Badwater specimens are almost identical to Orellan *Prosciurus relictus*. *Prosciurus* is the best represented of several genera of closely related rodents of the Prosciurinae. The subfamily Prosciurinae has been regarded as a member of the family Ischyromyidae (as that group is defined by Black, 1971:181) or the Paramyidae (Wood, 1955:171; Wood, 1962:226). A slight variation in the classification is presented by Wood (1973), in which the Prosciuridae is considered a separate family.

Recently, Rensberger (1975) transferred the Prosciurinae from the Ischyromyidae or Paramyidae to the Aplodontidae. The aplodontid taxa are segregated as Prosciurinae, Allomynae, and Aplodontinae. I agree with him. Here, *Prosciurns* and *Pelycomys* are treated as members of the Aplodontidae.

***Pelycomys placidus* Galbreath, 1953**

(Fig. 16, Table 6)

Referred specimens.—P⁴-M³: CM 33101; P⁴: CM 33102, CM 33103; M¹ or M²: CM 33104, CM 33105; M³: CM 33106, CM 33120; P₄-M₂: CM 19792; M₂: CM 17042; M₃: CM 33107, CM 33108.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—The lower jaw is relatively deeper and shorter than that of *Prosciurus relictus*. The incisor is characterized by greater compression laterally than in *Prosciurus*. The internal face of the incisor is flat, the anterior face is rounded, and the external face is gently curved toward the posterior border of the internal face, as Galbreath (1953) described.

The lower cheek teeth are subtriangular to subrhombic in shape. On P₄, the principal cusps are rounded and large. The trigonid is elongated transversely. The protoconid is tall and somewhat compressed anteroposteriorly. The metaconid is the tallest of the principal cusps. It lies on the anterolingual corner of the tooth. Metalophulid I is absent and the protoconid and the metaconid are separated by a deep notch, which runs antero-buccal from the posterobuccal base of the metaconid. Metalophulid II is very weak but present and unites the protoconid and the metaconid posteriorly. The mesostylid is tiny and low in position. The metastylid crest runs downward and posteriorly from the metaconid, and unites with the mesostylid. The mesoconid is small and rounded. The buccal mesolophid is absent so that a wide valley opens buccally between the protoconid and the hypoconid. The entolophid is a rather wide ridge and descends posteriorly from the posterolingual corner of the protoconid. The ectolophid, posterior to the mesoconid, turns posterobuccal and unites with the lingual corner of the transversely elongated hypoconid. The hypoconid is stout forming the posterobuccal corner of the tooth. The posterolophid is prominent. It unites with the posterolingual corner of the hypoconid but does not unite with the entoconid. The entoconid is rather small but is a distinct cusp, which is higher than the mesoconid. The hypolophid runs buccally from the entoconid and turns slightly posteriorly and joins the ectolophid between the hypoconid and the mesoconid. The lingual half of the hypolophid is wide and the anterior slope is more gentle than the posterior one so that the basin between the hypolophid and the trigonid becomes narrower transversely. The buccal half of the hypolophid is thin and low. A distinct transverse valley separates the hypolophid from the posterolophid. The entoconid is separated from the mesostylid by a deep notch.

M₁ has a complete metalophulid I, which runs anterad from the protoconid and soon turns linguad. The metalophulid II is also complete but lower than the metalophulid I. A basin is formed on the trigonid between the metalophulids, and the protoconid and the metaconid. The mesoconid has a tiny buccal mesolophid and tends to divide the valley between the protoconid and the hypo-

conid into two parts. The hypolophid is wider than on P₄ and runs buccally. The buccal ends connects to the ectolophid posterior to the mesoconid; near the buccal end it becomes narrower. The basin between the hypolophid and the trigonid is deeper than on P₄ and the notch which separates the entoconid from the mesostylid is also deeper than in P₄.

M₂ agrees with M₁ in general morphology. The mesoconid is more prominent than in P₄ and M₁. The mesoconid itself divides the valley between the protoconid and the hypoconid into two parts; the posterior part is wider than the anterior part. The ectolophid posterior to the mesoconid runs posteriorly and slightly lingually, and turns posterobuccally. The buccal slope is gentle so that the valley between the mesoconid and the hypoconid is long transversely in an unworn stage but becomes shorter with wear. The posterolophid is also prominent and tends to have a distinct cusp near its union with the hypoconid. The hypolophid is taller than in M₁ and connects to the ectolophid more posteriorly than in M₁. The basin between the hypolophid and the trigonid is more widely open than in P₄ and M₁.

On M₃, the protonid is low but the metaconid is high. Although the metalophulid I is complete, the metalophulid II is incomplete on the metaconid side. The basin between the metalophulids is wider than in M₁ and M₂, and opens posterolingual. The talonid basin becomes wider and the difference in height between the talonid basin and the trigonid is reduced. The mesoconid is large and divides the valley between the protoconid and the hypoconid into two parts. The hypoconid is massive and its buccal arm extends anteriorly to the protoconid enclosing the large mesoconid buccally. The entoconid is distinct but the hypolophid is weakened. The hypolophid runs posterobuccally making the talonid basin wider. The valley between the posterolophid and the hypolophid is wider and deeper than in the rest of the cheek teeth.

A maxilla and a few isolated teeth are tentatively assigned to this species. The size of these agrees with that of the lower teeth of the species. They are not associated with any lower jaws so that whether or not they are referable to *Pelycomys* remains uncertain, as only lower cheek teeth of *Pelycomys* are known. On P⁴, the parastyle is prominent. The protocone is elongated anteroposteriorly. The protoconule and the metaconule are subequal, but only the former connects to the protocone by the thin protoloph. After heavy wear, the metaconule will unite with the protocone. The posterior crest of the protocone runs posterad and continues to run transversely as the posterior cingulum. Near the union of the posterior crest with the posterior cingulum, a small hypocone is present. The metaloph unites the metacone and the metaconule on their anterior side. A tiny but distinct mesostyle is present between the paracone and the metacone on the buccal border of the tooth.

All the specimens referable to M¹ and M² are heavily worn. A parastyle seems to be present on the buccal end of the anterior cingulum. The posterolingual corner of the tooth extends linguad indicating the presence of the hypocone.

M³ is triangular in shape. The anterior crest of the protocone is heavy. The buccal end of the anterior cingulum has a wide base. The paracone is elongated anteroposteriorly. The protoconule is tiny and situated just between the protocone and the paracone. The protoconule connects to the protocone by a ridge. The basin between the protoloph and the anterior cingulum is wide. Posterior to the protoloph is a broad basin. Only a tiny metaconule is present and it is completely isolated. The posterior crest of the protocone, the posterior cingulum, and the buccal cingulum surround the basin.

Discussion.—The present form differs from *Prosciurus* in having the following morphology: incisors are laterally compressed; on lower cheek teeth, metalophulid II is essentially complete; hypolophulid is well developed and separated from the posterolophid. These are the diagnostic features of *Pelycomys*.

Galbreath (1953) recognized two species of *Pelycomys*—*P. rugosus*, the type species, and *P. planidus*. *P. planidus* differs from *P. rugosus* in having narrower trigonids, better developed mesoconids, and weaker and lower metalophulid II than metalophulids I.

The Badwater specimens are almost identical to *Pelycomys planidus*.

Family Eomyidae Deperet and Douxami, 1902

***Adjidaumo douglassi* Burke, 1934**

(Fig. 17, Table 6)

Referred specimens.—M¹ or M²: CM 33702, CM 33703; P₁-M₁: CM 33697; P₄: CM 33698; M₁-M₂: CM 33699; M₁: CM 33700; M₂: CM 33701.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description and discussion.—The morphology of the mandible is very similar to that of *Adjidaumo minimus*. The mandible is long and slender. The mental foramen lies anterior to P₄ and almost on the dorsal surface of the mandible. The masseteric fossa ends rather acutely below the talonid of P₄. The dorsal masseteric ridge is stronger than the ventral and rises gently to the ascending ramus, which originates opposite the posterior half of M₂.

The crown pattern of the lower cheek teeth of *A. douglassi* differs from that of *A. minimum* and *A. minutus*. In *A. minimus*, the protoconid and the hypoconid are on the buccal side of the tooth, and the ectolophid also lies on the buccal margin to the midline of the crown. But in the type of *A. douglassi*, the protoconid and the hypoconid lean lingual making the buccal wall of each cusp more gentle and pushing the ectolophid towards the mid-

line of the crown. The difference in morphology of these two types is clearly seen on worn specimens. When worn, the ectolophid in *A. minimus* lies buccally, whereas it in *A. douglassi* lies near the center of the crown. In *A. minimus*, the protoconid and the hypoconid are more stout than in *A. minutus* and *A. douglassi*. M₂ of *A. minutus* is wider than long, whereas M₂ of both *A. minimus* and *A. douglassi* is clearly longer than wide. *A. minutus* is larger than both *A. minimus* and *A. douglassi*, which are essentially of the same size. *A. douglassi* is a direct descendent from *A. minimus* but not via *A. minutus*.

All the specimens in the Badwater fauna are well worn. The P₄ has a narrower trigonid, almost half as wide as the talonid. The ectolophid lies near the midline of the tooth. No indication of the mesolophid is seen.

M₁ and M₂ have essentially the same morphology. M₁ is clearly longer than wide. One specimen of M₁ has a little narrower anterior half than the posterior but another specimen has the same anterior and the posterior width. On M₂, the anterior half is wider than the posterior half on the type of *A. douglassi* and CM 33701. The anterior cingulum is joined to the base of the metaconid and by a short crest to the metalophid where the latter leaves the protoconid. The buccal end of the cingulum is apparently free. These features are also found in *A. minimus*. The mesolophid is short on all the specimens passing half way to the lingual border on M₁ and M₂. The ectolophid lies near the midline of the crown. No M₃s are present in the sample.

The upper dentition of *Adjidaumo* has not been adequately described and figured. Wood (1937:237–238) briefly discussed the morphology of upper molars of this genus but did not figure them. The upper cheek teeth of *Adjidaumo* in the present fauna are identified based primarily on size and the mirror imaged structure of the lower molars referable to *A. douglassi*. Only two heavily worn specimens are identified. Both of them are M¹ or M². The anterior

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Fig. 17.—*Adjidaumo douglassi*. a: CM 33699, right M₁-M₂. b: CM 33703, left M¹ or M². ×8. Fig. 18.—*Paradjidaumo hypsodus*, new species. a: CM 33707, right P₄. b: CM 33704, holotype, right M¹. c: CM 33723, right M². d: CM 33732, right P₄. e: CM 33743, right M₁. f: CM 33752, right M₂. ×8. Fig. 19.—*Metadjidaumo hendryi*, new genus and new species. a: CM 33775, right P₄, ×8. b: CM 33780, left M¹, ×8. c: CM 33783, left M², ×15. d: CM 33784, left P₄, ×8. e: CM 33786, holotype, left M₁, ×8. f: CM 33808, left M₂, ×8. Fig. 20.—Eomyidae, genus indet., Type A. a: CM 33811, right M². b: CM 33812, right M₁. ×8. Fig. 21.—Eomyidae, genus indet., Type B. a: CM 33813, right P⁴-M¹. b: CM 33815, right P₄. c: CM 33816, lower molar? ×8. Fig. 22.—*Proheteromys* sp. cf. *P. nebraskensis*. a: CM 33818, left M¹, ×8. b: CM 33846, left M², ×8. c: CM 33857, right M¹, ×15. d: CM 33884, left M₂, ×8.

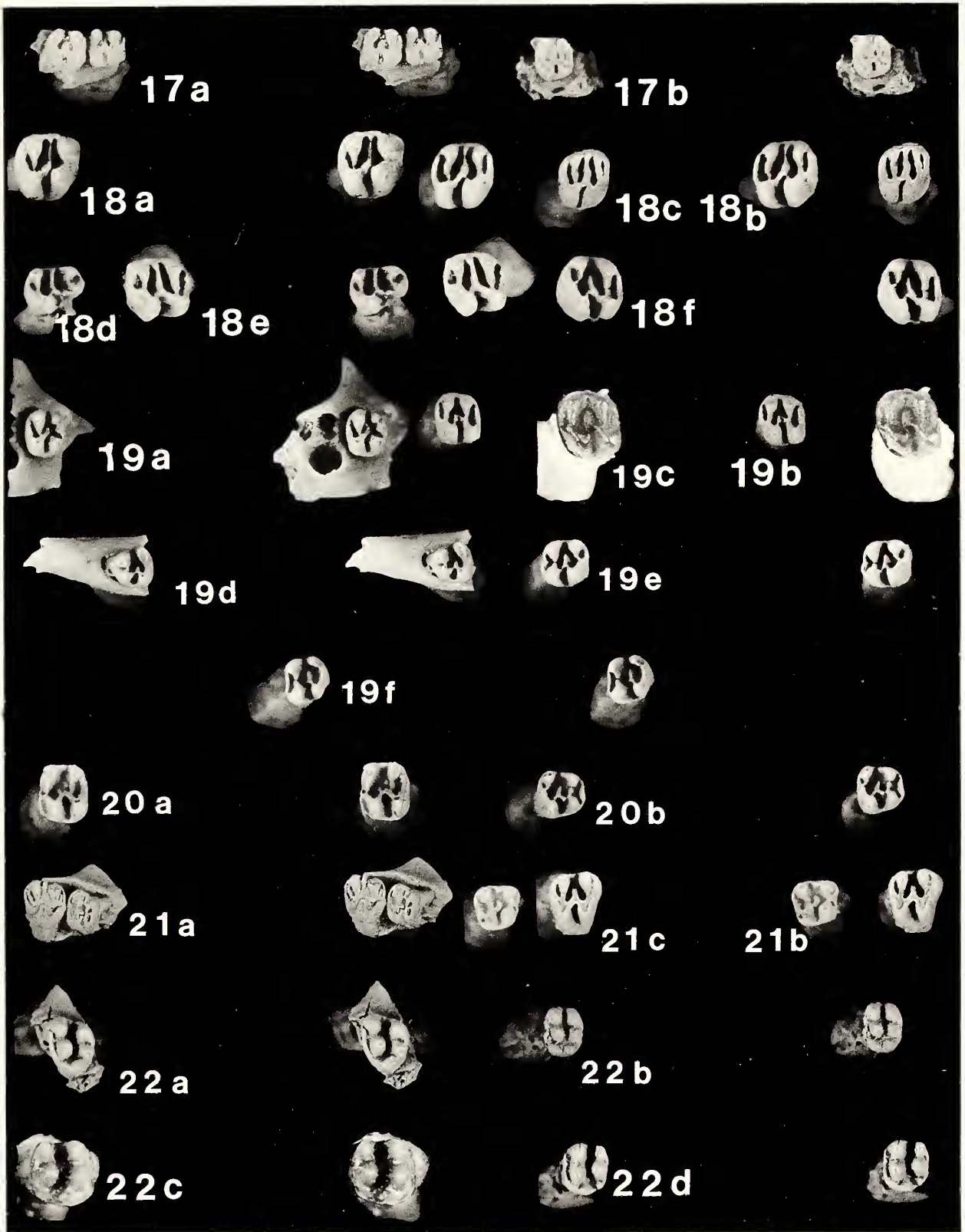


Table 6.—Dimensions of teeth of *Pelycomys placidus* and *Adjidaumo douglassi*.

Teeth and measurements	<i>Pelycomys placidus</i>			<i>Adjidaumo douglassi</i>		
	N	OR	Mean	N	OR	Mean
P ¹						
Length	3	2.13–2.57	2.353			
Width	3	2.30–2.96	2.600			
M ¹						
Length	1	2.41				
Width	1	3.09				
M ²						
Length	1	2.49				
Width	1	3.27				
M ¹ or M ²						
Length				2	0.87–0.91	
Width				2	0.94–0.97	
M ³						
Length	2	2.62–2.78				
Width	2	2.75–2.88				
P ₄						
Length	1	2.72		2	0.78–1.02	
Width				2	0.76–1.05	
Anterior	1	1.90				
Posterior	1	2.56				
M ₁						
Length	1	2.47		3	0.91–0.93	0.920
Width				3	0.79–0.88	0.847
Anterior	1	2.21				
Posterior	1	2.86				
M ₂						
Length	2	2.51–2.72		2	0.92	
Width				2	0.91–0.95	
Anterior	1	2.10				
Posterior	2	2.66–2.93				
M ₃						
Length	2	3.19–3.48				
Width						
Anterior	2	2.64–2.73				

cingulum is restricted on the buccal half of the tooth, whereas the posterior cingulum is well developed. The mesoloph is short and extends only half way to the buccal border. Union of the mesoloph to the metaloph is at almost the midline of the crown. The mesoloph is connected to the protocone.

***Paradjidaumo hypsodus*, new species**
(Fig. 18, Table 7)

Holotype.—CM 33704, isolated right M¹.

Hypodigm.—Type and P⁴: CM 33705–33708; M¹: CM 17097, CM 33709–33718; M²: CM 33719–33730; M³: CM 33731; P₄: CM

17436, CM 19808, CM 33732–33742; M₁: CM 17437, CM 17440, CM 33743–33743; M₂–M₃: CM 33749; M₂: CM 17433, CM 33750–33762; M₃: CM 33763–33769.

Etymology.—Hypsodont *Paradjidaumo*.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Diagnosis.—Higher crowned than *P. trilophus*—cusps and lophs (lophids) are higher and valleys are deeper than in any other known species of *Paradjidaumo*.

Description.—The cheek teeth of *Paradjidaumo* are mesodont, showing in relation to other eomyids an increase in the height of the cross lophs and lophids as well as increase in height of cusps (Black, 1965:26). The teeth of the present species are more advanced in this character than are those of *P. trilophus*.

P⁴ is essentially molariform. It differs from M¹ and M² primarily in the absence of the anterior cingulum. On one specimen (CM 33705), however, a very narrow and shallow scar is present below the lingual end of the paracone on the anterior face of the tooth and the scar is covered anteriorly by a thin, short ridge. This ridge may be a remnant of the anterior cingulum and the scar, a remnant of the anterior valley. The scar is low in position so that it would be obliterated only after considerable wear. On the other specimen (CM 33707), no trace of an anterior cingulum and an anterior valley are seen. The protocone and the paracone are elongated transversely forming elongated blades. The buccal part of the protocone and the lingual part of the paracone run slightly anterad and join together at an angle below the tips of both cusps which are of the same height. The mesoloph reaches across the crown to a tiny mesostyle. The mesocone is well defined situating closer to the protocone than to the hypocone. The anterobuccal corner of the mesocone is very close to the posterobuccal corner of the protocone but apparently they are not connected to each other. This is a situation of the incipient separation of the protocone and the protoloph from the mesoloph as seen in some of the European forms, like *Pseudotheridomys*. The posterior cingulum is well developed but the valley between the metaloph and the posterior cingulum is not deep so that these elements become fused into a single loph with further wear. The base of each cusp is broad as in *P. trilophus* but the tips of these cusps near the unworn crown surface are high above the base and become compressed anteroposteriorly leaving deep valleys between the cusps and the mesoloph. These valleys are deeper than in *P. trilophus*.

M¹ differs slightly from M² in crown pattern. The anterior cingulum is distinct on both M¹ and M² when the teeth are unworn but restricted to the lingual half of the crown. It quickly merges with the protoloph as wear proceeds. The posterior valley is deeper than the anterior valley so that the former remains distinct somewhat longer but it also eventually fuses with the metaloph, producing the "Omega" pattern as in *P. minor* and *P. trilophus*. The protocone is pushed posterolingual so that the anterior half of the crown is narrower transversely than the posterior half on M¹. On M², both halves are of the same width or the anterior half is a little wider. The mesostyle is tiny but distinct. It is lower than both the paracone and the metacone, and separated from them by notches on M¹. The mesoloph reaches to the mesostyle across the crown surface. On M², the mesostyle is more prominent and higher than in M¹, and united to both the paracone and the metacone forming the lingual wall to block the

Table 7.—Dimensions of teeth of *Paradjidaumo hypsodus*, new species, and *Metadjidaumo hendryi*, new genus and new species.

Statistics	P ¹		M ¹		M ²		P ₄		M ₁		M ₂	
	L	W	L	W	L	W	L	W	L	W	L	W
<i>Paradjidaumo hypsodus</i> , new species												
N	4	4	10	10	12	12	10	10	6	6	11	11
OR	1.28– 1.58	1.32– 1.50	1.17– 1.54	1.29– 1.88	1.20– 1.62	1.34– 1.72	1.21– 1.60	0.93– 1.36	1.29– 1.44	1.34– 1.51	1.30– 1.49	1.40– 1.62
Mean	1.432	1.405	1.384	1.519	1.389	1.542	1.387	1.164	1.352	1.415	1.366	1.482
SD			0.140	0.174	0.139	0.120	0.115	0.159	0.050	0.071	0.062	0.066
CV			10.14	11.48	9.98	7.77	8.29	13.70	3.73	5.01	4.53	4.42
<i>Metadjidaumo hendryi</i> , new genus and new species												
N	8	8	6	6	2	2	1	1	12	12	13	13
OR	0.95– 1.12	0.96– 1.21	0.97– 1.07	1.03– 1.27	1.04– 1.09	1.11– 1.13	0.98	0.95	0.96– 1.13	0.94– 1.15	0.90– 1.04	0.94– 1.12
Mean	0.970	1.061	1.018	1.175					1.034	1.074	0.991	1.066
SD	0.070	0.084	0.034	0.088					0.066	0.067	0.038	0.053
CV	7.27	7.87	3.31	7.53					6.39	6.22	3.85	5.00

central valley buccally. The buccal corner of the metacone is elongated anteriorly to join the mesostyle so that the metacone and the paracone are closer together on M² than on M¹. The central valley is deeper on both M¹ and M² than in *P. trilophus* and *P. minor*. The mesocone is not well defined on either M¹ or M². The anterior extremity of the anterior arm of the hypocone is very close to the protocone. They are united by a short, thin ridge on M¹, and by a thicker ridge on M². This condition, especially of M¹ is close to that of P¹, but no specimens available of M¹ show closer separation of them.

M³ is the smallest of the upper cheek teeth but the crown elements are not as greatly reduced as in *P. minor*. The protocone and the paracone are the largest cusps and they are joined by a strong protoloph as in *P. minor*, but the protocone lies more anteroposteriorly than in *P. minor*, and the anterior extremity of the protoconal ridge ends more lingually. The anterior cingulum is longer than in *P. minor*. All lophs rise to the same level as the protocone leaving rather deep valleys. On one specimen (CM 33731), the posterior valley is shallow but distinct. On the other, it is represented by a small pit. The mesoloph reaches to the lingual wall. No mesostyle is visible. The central valley anterior to the mesoloph is deeper than the posterior one which, in turn, is deeper than the anterior valley. This molariform morphology of M³ in the present species is unusual.

P₄ is longer than wide. The crown height is almost the same as in *P. trilophus*. The trigonid is higher than the talonid, but less prominent than in *P. trilophus*. The protocone and the metacone are closely appressed and bounded posteriorly by the thin metalophid. A short anterior cingulum descends sharply from the anterior face of the protoconid to merge into the base of the metaconid. The posterior arm of the protoconid extends posteriad and connects to the mesolophid at right angle. The mesolophid extends transversely to the buccal border of the tooth and there turns anterad at a right angle to connect to the posterior base of the metaconid. The mesoloph is a thin ridge and slightly higher than the lingual wall of the tooth. The hypoconid forms a ridge, which extends more anteroposteriorly than in *P. trilo-*

phus. The talonid is narrower in relation to the crown length to make the tooth longer than in *P. trilophus*. In *P. minor* and *P. trilophus*, a rather broad and deep excavation is present on the buccal wall of the tooth between the protoconid and the hypoconid. In the present species, this pit becomes shallower and narrower, and the excavated rather posteriad on the anterior base of the hypoconid. On some specimens (CM 33732), the central valley posterior to the mesolophid is deeper than the anterior one, but on one specimen (CM 33738) these two are essentially of the same depth.

M₁ is slightly longer than wide, whereas M₂ is rather wider than long. Both M₁ and M₂ are higher crowned than in *P. minor* and *P. trilophus*. Cusps become less prominent than in other species of *Paradjidaumo*. The anterior and posterior cingula, the metalophid, and the hypolophid lie essentially on the same level as the protoconid and the hypoconid, which are no more distinct cones but rather thin, elongated ridges. The metaconid is a sharp-pointed cusp slightly above the level of lophids. The metalophid descends transversely from the peak of the metaconid. Only the metalophid is slightly higher than the remainder of the cross lophids in an unworn stage. The entoconid is a small knob. On M₁, the mesolophid reaches to the lingual border of the tooth on all specimens available but on M₂, some specimens show that the mesolophid ends in the center of the crown. The central valley is deep. On some specimens of M₂, the trigonid is higher than talonid. The anterior cingulum of M₂ is not as closely appressed to the metalophid as in *P. minor*, but on some (CM 33752) the former is appressed to the latter. The posterior cingulum is short and is confined to the lingual quarter of the posterior face of the tooth on M₁ and M₂.

M₃ differs from M₁ and M₂ primarily in the absence of the posterior cingulum. M₃ in *P. minor* and *P. trilophus* have essentially the same crown pattern as M₁ and M₂. But in M₃ of these species of *Paradjidaumo* the crown elements are reduced. In the present species, as far as M₃ is concerned, the same trend is retained. The mesolophid reaches to the entoconid across the crown surface, instead of reaching to the lingual wall between

the metaconid and the entoconid as in M_1 and M_2 . The hypolophid forms a posterior wall and is convexed posteriorly. The crown is also higher than that of *P. minor* and *P. trilophus*.

Discussion.—*P. hypsodus* differs from *P. minor* and *P. trilophus* in having more hypsodont teeth. In *P. minor*, the cheek teeth are not high crowned, and the paracone and the metacone on the one hand, and the metaconid and the entoconid on the other are elevated high above the cross lophs and lophids. In *P. hypsodus*, however, the lophs, the lophids, and the cusps are elevated to a nearly common plane. The paracone and the metacone on the upper cheek teeth, and the metaconid and the entoconid on the lower teeth rise only slightly above the lophs and the lophid. In relation to the high lophs and lophids, the protocone and the hypocone on the upper teeth become higher, forming elongated ridges elevated to the same plane as the cross lophs. The lower cheek teeth show exactly the same trend. The cheek teeth of *P. hypsodus* are characterized by strong lophs and lophids rather than being cuspidated. This situation is analogous to the tooth character of *Eumys planidens* discussed elsewhere in this article.

The cheek teeth of *Paradjidaumo hypsodus* become higher crowned. Not only the lophs and lophids, but also the cusps become elevated as if elongated ridges were developed on the summit of the original cusps. The base of each elongated cusp is thick and broad showing the cuspidate condition of the ancestral stock to *P. hypsodus*. This condition could easily be derived from the tooth pattern of *P. trilophus*. As for the height of the crown of the cheek teeth, *P. trilophus* is intermediate between *P. minor* and *P. hypsodus*. The crown patterns of these three species of *Paradjidaumo* are essentially the same.

The essentially unreduced morphology of M^3 is worth discussing. Although the posterior cingulum is reduced, M^3 of *P. hypsodus* has all other crown elements, whereas on M^3 of *P. minor* the crown elements are reduced. In the latter, the size is not greatly reduced although it is a little smaller than M^1 and M^2 . M^1 and M^2 of *P. hypsodus* have high lophs, and M^3 also follows this trend so that lophs and elongated cusps become emphasized in this species. The reduction of M^3 is a trend in the central stock of *Paradjidaumo* with increased hypsodonty; however, M^3 is modified to emphasize all the molar elements. This kind of rejuvenation is not common in rodent evolution.

Metadjidaumo, new genus

Type species.—*Metadjidaumo hendryi*, new species.

Etymology.—From Greek *metá*, *met-* after, descent of *Adjidaumo*.

Diagnosis.—Near size of *Adjidaumo minimus* and *A. douglassi*; molars higher crowned than in *A. minimus* and *A. douglassi* with high, thin lophs (lophids); trigonid higher than talonid on M_1 and M_2 ; no posterior cingulum on M_2 .

Metadjidaumo hendryi, new species

(Fig. 19, Table 7)

Holotype.—CM 33786, isolated left M_1 .

Hypodigm.—Type and P^4 - M^1 : CM 33770, CM 33771; P^4 : CM 33772–33777; M^1 : CM 17435, CM 33778–33780; M^2 : CM 33781–33783; P_4 : CM 33784; M_1 - M_2 : CM 33785; M_1 : CM 17439, CM 33787–33796; M_2 : CM 17438, CM 33797–33808.

Etymology.—For Mr. Jim Hendry, who provided his cabin during field seasons.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Diagnosis.—Only known species of genus.

Description.—The fourth upper premolar is square-shaped. All the cusps are well developed. Among them the metacone and the hypocone are taller than the paracone and protocone. The anterior half is narrower transversely than the posterior half. There is considerable variation in the morphology of the anterior half of the crown. The protocone is stout and extends anterobuccally leaving a narrow valley between it and the hypocone. The valley runs slightly posterad on CM 33775 as in M^1 or M^2 , whereas the protocone is shifted more buccally from the usual position so that the valley between the protocone and the hypocone runs rather anterad on CM 33777. The protoloph is a thick ridge extending anterobuccally from the protocone and joining the paracone at its anterolingual corner. On two specimens, no anterior cingulum is seen. On other specimens, however, a very shallow, compressed pocket is present on the anterior face of the paracone which is bounded anteriorly by what is probably a short anterior cingulum that fades into the anterior face of the paracone. This pit would be obliterated with further wear. The mesocone is well defined on CM 33775. It is half as large as the protocone and is a little lower than the latter. The mesoloph is essentially not present on this specimen. On the other specimens, the mesocone is merely a buccal extension of the anterior arm of the hypocone and quickly merges with the floor of the crown near the posterolingual base of the paracone. On three specimens, the mesocone or a thin ridge, the mesoloph, is connected to the protocone by what may be called the posterior arm of the protocone. On one specimen, the mesocone and the protocone are close together but no connection is seen between these cusps, and on one other specimen, these two cusps are clearly separated from each other. The separation of the protocone from the mesoloph is not common in North American eomyids, but this characteristic feature is commonly seen

in European eomyids. In four specimens, no metastyle is present, but on others the metastyle is present on the buccal border at the posterior base of the paracone. The posterior cingulum is well developed but the posterior valley is shallower than the central valley.

Only two upper jaw fragments, both of which bear P^4 and M^1 , are available and M^1 on both is heavily worn. M^1 is clearly wider than long on both specimens. One specimen (CM 33771) has a wider posterior half than anterior, and the other (CM 33770) is nearly square. The valley between the protocone and the hypocone is narrow and long reaching to nearly the center of the crown. The valley runs almost transversely but a little posteriad. The ectoloph or mure lies at the center of the crown on CM 33770 and a little buccal to the midline of the tooth on CM 33771. The mesoloph is short. The buccal halves of the paracone and the metacone are curved posterad and anterad, respectively, so that the central valley becomes narrower buccally. On worn teeth, the lingual three-fourths of the crown is flattened, whereas the buccal one fourth remains a little higher. On CM 33771, the buccal portion of M^1 is not completely worn with the buccal wall between the paracone and the metacone unworn although both cusps are worn. This indicates that on M^1 the buccal wall between these two cusps is low and not elevated to block the central valley buccally. This condition is also seen on M^1 of *Paradjidaumo*. On M^2 of *Paradjidaumo*, however, the buccal wall between the paracone and the metastyle, and between the latter and the metacone is elevated nearly to the level of these three cusps so that the central valley is blocked buccally by this wall.

No unworn definite M^1 or unworn M^2 associated with P^4 on the same jaws are available in the present fauna. This makes it difficult to identify M^1 and M^2 of the new genus and species. Isolated M^1 and M^2 are identified on the basis of size and similar morphology with the low buccal wall between the paracone and the metacone for the former and with the high wall between them for the latter.

M^1 and M^2 are of similar size and the crown pattern is essentially the same. The size is very close to *Adjidaumo minimus*, but a little larger. The crown is definitely higher than in *A. minimus* and *A. douglassi*. The ratio of the crown height to the width is nearly 1.0 in the present form, whereas it is clearly below 1.0 in *Adjidaumo douglassi* and is definitely over 1.0 in *Paradjidaumo hypsodus*. The molars emphasize ridges rather than stout cusps. The protocone is elongated sending a thick anterior arm anterobuccally. From the anterobuccal corner of the arm the anterior cingulum extends buccally and reaches to the anterior base of the paracone. The anterior cingulum is restricted to the buccal half of the crown. A short, transverse protoloph unites the anterior arm of the protocone and the transversely elongated paracone. The hypocone projects more lingually than the protocone. The buccal tip of the hypocone is excavated making the posterior valley longer transversely. The anterior arm of the hypocone extends to the center of the crown, and there it turns anterad making what may be called the mure. A short mesoloph runs buccally; it does not reach to the buccal border of the crown. The posterior cingulum is well developed from the tip of the hypocone to the posterior base of the metacone. On some specimens, the union of the protocone and the mesoloph is seen by way of the posterior arm of the protocone, but on some, the connection is by a thin ridge (CM 33780, M^1 and CM 33783, M^2), and almost no connection is seen (CM 33782, M^2), where the

mesoloph connected to the anterior arm of the hypocone. No metastyle is seen on any of the specimens.

No lower jaw materials associated with upper jaws are available. The lower molars are identified primarily based on size and the mirror image morphology of the upper molars. P_4 is also identified based on size and the similar morphology to M_1 and M_2 .

One lower jaw fragment (CM 33784) has P_4 . The diastema is not deep and essentially the same as that of *Adjidaumo*. P_4 is larger than that of *Adjidaumo douglassi* and wider than M_1 of *A. douglassi*. The trigonid is narrower than the talonid. The protoconid and the metaconid are of equal size and are joined posteriorly by a short crest. The anterior valley between the cusps is open. The mesolophid is short and ends half way across the crown. The mesoloph is lower than the ectolophid. No posterior cingulum is present on one specimen (CM 33784) but on the other specimen a small pit is present just posterobuccal to the entoconid and the pit is bounded posteriorly by what is probably a short posterior cingulum that fades into the posterior face of the entoconid.

One lower jaw (CM 33785) has M_1 and M_2 . These teeth are well worn. M_1 is clearly longer than wide and a short posterior cingulum is present. M_2 is rather wider than long and has no posterior cingulum. Isolated M_1 and M_2 are identified solely on the basis of this morphology—longer teeth with the posterior cingulum for M_1 and wider teeth without the posterior cingulum for M_2 . The following morphology is described based on isolated teeth referable to M_1 and M_2 . M_1 differs only slightly from M_2 in crown pattern. The anterior cingulum is distinct on both M_1 and M_2 but unlike *Adjidaumo* it does not connect to the metalophid. The anterior cingulum extends from near the anterior base of the metaconid to the anterobuccal corner of the protoconid. On one specimen (CM 33793, M_1), the anterior cingulum is separated from the protoconid by a small notch, and nearly so on the holotype, CM 33786, also M_1 . On the other specimen (CM 33795, M_1), the lingual half of the protoconid is excavated and the anterior cingulum is connected to the protoconid on its anterior side. All the specimens except for one referable to M_2 are worn at least on the trigonid. On this unworn specimen (CM 33808), the morphology of the anterior cingulum is close to CM 33795; connection to the protoconid is as in *Paradjidaumo*. The trigonid is clearly higher than the talonid. The metaconid is the most prominent cusp and a little taller than the protoconid. The entoconid is conical and higher than the hypoconid, but lower than the protoconid. From the protoconid a short ridge descends linguad and meets a short ridge, which also descends buccally from the transversely elongated metaconid. These two ridges are arranged transversely and represent what is called the metalophid. The posterior arm of the protoconid runs posterolingual and meets the short anterior arm of the hypoconid. The junction lies near the center of the crown. From this junction, the mesolophid extends linguad only half way across the crown. The mesolophid is distinct and higher than in *Adjidaumo minimus* and *A. douglassi*. These three ridges are really lower than the trigonid and a little lower than the hypoconid. The posterior wall of the metaconid is vertical and the central valley is deeper than the anterior valley. A metastylid is not present. The metaconid is rather widely separated from the entoconid. The hypoconid is elongated and the posterior arm of it extends posterolingual. A short ridge runs posterobuccally from the buccal corner of the entoconid and meets the posterior hypoconid arm at a right an-

gle. From this junction, the posterior cingulum runs posterolingual but it does not connect to the entoconid so that the posterior valley opens lingually on M_1 . The posterior valley is essentially of the same depth as the central valley. On M_2 , the hypolophid marks the posterior margin of the crown and is convex posteriorly.

Discussion.—The present form differs from *Adjidaumo* in having higher crowned teeth and from *Paradjidaumo* in having weaker development of the mesoloph and mesolophid. The higher trigonid in this new genus is quite unique among the North American eomyids. I cannot find any form having the higher trigonid on the lower cheek teeth even among the European forms.

Except for the higher trigonid, primitive features characterize the tooth structure of this new form. The weakness of the mesolophs and the mesolophids and the emphasis on the separate cusps are primitive among eomyids, as discussed by Wood (1973). In these respects, *Paradjidaumo* and *Centimanomys* are more specialized in having long mesolophs and mesolophids. *Meliakrouniomys* is also specialized in having bilophate cheek teeth of which each loph is formed of two cusps and accessory structures are very small. *Namatomys* has a peculiar feature having the posterior protoconid arm fused to the base of the metaconid. *Viejadjidaumo* has M_1 with only the hypolophid but without the posterior cingulum. *Yoderimys* has a long lophid, which passes from the center of the anterior cingulum to the center of the metalophid on M_1 and M_2 . This removes *Yoderimys* from any close relationship with other eomyids. The narrow trigonid with near fusion of the protoconid and the metaconid on P_4 in *Aulolithomys* is also unique and suggests its isolated position within the family. These rather specialized features make it difficult to believe that any of these genera, *Namatomys*, *Viejadjidaumo*, *Meliakrouniomys*, *Yoderimys*, *Aulolithomys*, *Centimanomys*, and *Paradjidaumo*, could give rise to *Metadjidaumo*. *Adjidaumo* retains the most generalized features of the cheek tooth structure among North American eomyids.

The most remarkable modification seen in the present form from the original stock is the higher crowned cheek teeth. Although the posterior half becomes a little more highly elevated than in *Adjidaumo*, the anterior half becomes elevated above the posterior half, and the tendency is more emphasized on lower cheek teeth than upper. This gives us the impression that the trigonid becomes higher than the talonid as if these teeth might have

been rejuvenated to nearly the tribosphenic condition. This trend took place in correlation with the development of hypsodonty of cheek teeth; the rate of increase in height is higher on the anterior half than the posterior half making the trigonid taller than the talonid on lower cheek teeth. The trend towards hypsodonty is seen also in *Paradjidaumo hypsodus* in the present fauna, but a differential rate for height increase of different parts of a single crown is highly unusual.

The talonid is not as high as the trigonid in the present form. This could mean that the degree of modification on the talonid might not be as great as on the trigonid in the original form. Compared with the talonid structure of *Adjidaumo douglassi*, a great resemblance is seen between the talonid structure in the present form and *A. douglassi*. The hypoconid is elongated sending its posterior arm posterolingual. A short ridge originates from the buccal corner of the entoconid running posterobuccally and meets the posterior hypoconid arm rather nearer to its posterior end than to the hypocone. From the posterior end of the posterior hypoconid arm, the posterior cingulum runs lingual on M_1 . On M_2 , the posterior cingulum is reduced on *A. douglassi*, whereas it is gone on the present form. A short posterior protoconid and a short anterior hypoconid arm, and the transverse mesolophid make a triple junction near the center of the crown. The mesolophid is rather short and does not connect to either the metaconid or the entoconid so that two valleys anterior and posterior to the mesoloph join together and run further lingual. The hypoconid itself leans lingual so that the tip of it is situated rather closer to the midline of the crown. *Adjidaumo douglassi* and the present form share the common features listed above. This suggests that they have a common ancestry sometime in the mid-Oligocene. As I show elsewhere in this article, *A. douglassi* is a direct descendent from *A. minimus* of the early Oligocene but not via *A. minutus* of the middle Oligocene. The present form may stand on a side branch from *A. minimus*.

The trigonid structure of *Metadjidaumo* differs from that of *A. douglassi*, even though some similarities are seen. The protoconid is taller than the mesolophid and the ectolophid so that the latter connects to the protoconid on its posterior wall below the tip of this cusp on M_1 of *A. douglassi*. This is also true for M_1 of *Metadjidaumo* although the connection is well below the tip of the protoconid

Table 8.—Dimensions of teeth of *Eomyidae*, genera indet., Type A and Type B.

Statistics	P ¹		M ¹		M ²		M ¹ or M ²		M ₁	
	L	W	L	W	L	W	L	W	L	W
Eomyidae, genus indet., Type A										
N			1	1	2	2			1	1
OR			1.27	1.36	1.16– 1.21	1.29– 1.33			1.07	1.07
Eomyidae, genus indet., Type B										
N	3	3	1	1			2	2		
OR	0.78– 1.08	0.92– 1.08	0.98	1.08			1.23– 1.24	1.23– 1.31		
Mean	0.927	0.983								

because it is a greatly elevated cusp. On M₁ of *A. douglassi*, the metaconid has a wider base lingually and the base becomes narrower buccally. A ridge descends buccally but slightly anterad towards the buccal base of the metaconid and meets a short ridge descending linguad from the tip of the protoconid. The junction is well below the tips of the protoconid and the metaconid, and even below the anterior cingulum. These two ridges combined together are what is called the metalophid. This kind of condition may indicate the origin of the metalophid.

The same morphology is seen on M₁ of *Metadjidaumo*, although the metaconid and the protoconid are greatly elevated and share a common base. The elevation takes place almost vertically so that the posterior wall of the metaconid and the protoconid are vertical. The junction of two ridges descending from the tips of the protoconid and the metaconid are a little below the anterior cingulum. The anterior valley is not deep and its floor lies a little below the junction between two ridges just mentioned above. The presence of the rather shallow anterior valley indicates that the whole trigonid becomes elevated from the base of the crown.

The anterior cingulum is well developed and extends along the whole anterior face of molars on both *Adjidaumo douglassi* and *Metadjidoumo*. But here a major difference takes place between these forms. In the holotype of the *A. douglassi*, the anterior cingulum is joined to the anterolingual base of the protoconid, and the buccal part of the former is free but descends buccally joining to the protoconid far below on its anterobuccal base. In the

present form, the anterior cingulum does not connect to the metalophid but connects to the protoconid making the anterior valley longer transversely. The protoconid in *A. douglassi* is not as large and prominent when compared with the hypoconid, and on M₁, the trigonid is narrower than the talonid. On the other hand, in the present form, the protoconid is more prominent and stout than the hypoconid, and the trigonid is rather wider than the talonid on M₁ although the tooth itself is longer than wide. The wider trigonid could be associated with the heightening of this part.

Except for the union of the anterior cingulum with the protoconid and the wider trigonid, an overall similarity of crown structure is seen between *A. douglassi* and the present form. The absence of the posterior cingulum on M₂ in the present form should be mentioned. On M₂, the hypolophid forms the posterior border of the crown and the posterior cingulum is not present. This feature is highly specialized for M₂ and not seen commonly in the North America eomyids. *Viejadjidaumo* shows this feature even on M₁. On the holotype of *Adjidaumo douglassi*, the posterior cingulum is more reduced on M₂ than on M₁ because the posterior hypoconid arm extends more linguad on the posterior border of the crown on M₂. The short posterior cingulum runs linguad along the posterior margin of the crown and ends posterior to the entoconid, but does not connect to the latter. The posterior valley is represented by a shallow pocket. If the reduction proceeds, the situation without the posterior cingulum on M₂ will take place.

Eomyidae, genus indet., Type A
(Fig. 20, Table 8)

Referred specimens.—M¹: CM 33809; M²: CM 33810, CM 33811; M₁: CM 33812.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—Three isolated upper molars and one lower molar are available. They are low-crowned and of equal size. The determination of upper and lower molars are primarily based on the position of roots; both are three rooted; in upper molars, one anteroposteriorly elongated root is underneath the protocone and the hypocone, and two roots are underneath the paracone and the metacone, respectively; in lower teeth, one transversely elongated root is underneath the hypoconid and the entoconid, or underneath the talonid, and two roots are underneath the protoconid and the metaconid, respectively.

One upper tooth (CM 33809) is longer than wide, probably M¹, and this tooth is heavily worn. All the cusps are well defined and connected by rather thin ridges. The anterior cingulum is represented by a thin ridge, which is thinner than the posterior cingulum and extends along the whole anterior border of the crown. The buccal end of the anterior cingulum is connected to the anterior base of the paracone. A rather thick ridge connects the anterior cingulum with the anterobuccal corner of the protocone. The lingual portion of the anterior cingulum is free. The floor of the anterior valley is unworn as are the floors of the central and the posterior valleys. All three valleys are of equal depth. The base of the protocone is wider anteroposteriorly than the remainder of cusps. The protoloph is curved anteriorly making the anterior valley narrow. The central valley is wide and opens buccally. The mesoloph is not defined clearly. A short and rather thick mure connects the posterobuccal corner of the protocone with the metaloph. The posterior cingulum extends only half way to the buccal border along the posterior margin of the tooth. The posterior valley opens buccally.

Two upper molars are wider than long and are probably M²s. One of them (CM 33811) is almost unworn. The crown structure is almost the same as the one described just above. The four cusps are stout and rather tall, and all the ridges are thin and low in position; thus the crown pattern emphasizes cusps rather than ridges. The anterior arm of the protocone with a thick base descends from the stout protocone anterobuccally and its anterior extremity connects to the anterior cingulum. A ridge also with a thick base descends almost transversely from the paracone and joins the anterior protocone arm forming the protoloph. The posterior arm of the protocone descends linguad but slightly posterad and near the center of the crown turns posterad to join the anterior arm of the hypocone. The mesoloph is not well defined; two short, thin and low ridges are slightly elevated from the floor of the central valley just buccal to the mure—one is near the anterior end of the mure, and the other is near the middle of it. The buccal border between the paracone and the metacone is slightly elevated but well below the tips of these cusps. The posterior cingulum is rather long and connects to the metacone on its posterior base.

One lower molar (CM 33812) is longer than wide and the trigonid is narrower than the talonid. It is probably M₁. This tooth also emphasizes cusps rather than ridges. The anterior cingulum is well developed extending along the whole width of the tooth.

The base of it is rather wide and it is not as close appressed to metalophid. The lingual end of the anterior cingulum is fused to the metaconid at its anterior base. The anterior cingulum does not connect to either the metalophid nor the protoconid so the V-shaped valley extends between the anterior cingulum and the metalophid, and opens buccally. The metaconid and the entoconid are conical and taller than the buccal cusps. The size of the entoconid is reduced compared with that in other eomyids. The metaconid and the entoconid are widely separated. No metastylid is seen. The hypoconid is more stout than the protoconid. The hypolophid is the most prominent of the ridges. The rather weak metalophid connects the protoconid with the metaconid. The ectolophid is also weak and lower in position than both the metalophid and the hypolophid. The mesolophid is short and as weak as the ectolophid. The mesolophid extends linguad only half way to the lingual border and merges to the floor of the central valley posterior to the metaconid. The posterior cingulum is short and restricted to only the lingual quarter of the posterior margin. The posterior valley is represented by a small pocket situated posterolingual to the entoconid.

Discussion.—In size this form is close to *Adjidaumo douglassi* but is a little larger than it. The well developed cusps and weakness of lophs and lophids in the present form are unusual among eomyids. The reduction of the entoconid is seen on M₂ in *Adjidaumo douglassi* as compared to this cusp on M₁ of this species. This, together with the well-developed anterior cingulum indicates the close relationship of this form to *Adjidaumo*. In *Adjidaumo*, lophs and lophids are better developed than in the present form. At present, I cannot find any close relation of this form to any other eomyids.

Eomyidae, genus indet., Type B
(Fig. 21, Table 8)

Referred specimens.—P¹-M¹: CM 33813; P⁴: CM 33814, CM 33815; M₁ or M₂: CM 17434, CM 33816.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Description.—An upper jaw fragment (CM 33813) with P⁴ and M¹ is available. Size is close to *Adjidaumo douglassi*. Both teeth are heavily worn but they are higher crowned than in *A. douglassi*. Unlike *Adjidaumo*, the mesoloph is long and reaches across the crown surface to the mesostyle, which is thin and elongated transversely on M¹. Both the paracone and the metacone are elongated transversely and of equal size. The anterior and the posterior cingula are well developed and both are restricted only on the buccal half of the tooth. The anterior cingulum is closely appressed to the protoloph. No lingual portion of the anterior cingulum is seen. The protocone and the hypocone are close together, and the valley between them is narrow running linguad and posterad as well.

The fourth premolar associated with M¹ on the same upper jaw is heavily worn. Two isolated P⁴s (CM 33814, CM 33815) are present. A root beneath the paracone of these teeth extends

anterobuccally indicating that the tooth is the first tooth of the cheek tooth series. All the cusps are well defined. The hypocone is the largest and extends more lingual than the protocone so that the posterior half is wider than the anterior half. A short anterior cingulum is present on the buccal quarter of the anterior margin of the tooth. This cingulum does not connect to the paracone. The mesoloph extends only half way across the crown to the buccal border. No mesostyle is present but the buccal border between the paracone and the metacone is slightly elevated. The posterior cingulum is long and connects to the hypocone on its posterobuccal corner making the posterior valley longer transversely. The lingual half is narrower anteroposteriorly than the buccal half.

Two isolated lower molars (CM 17434, CM 33816) are at hand. On both, the buccal half is narrower anteroposteriorly than the lingual half. Both specimens have the well-developed anterior cingulum connecting to the tip of the protoconid. The central valley is deeper than the anterior valley. The lingual wall is elevated with a thick base, but it is below the metaconid and the entoconid. A mesostylid is present on one specimen but not on the other. The mesolophid is well developed reaching to the buccal wall but the connection is below the mesostylid. The posterior cingulum is not present.

Discussion.—The above described specimens are characterized by small size, long mesolophs and mesolophids, narrower lingual half on upper and buccal half on lower teeth, and high-crowned teeth. Some similarities between this form and *Paradjidaumo* are seen—higher-crowned teeth, long mesolophs and mesolophids, and anterior cingulum connecting to the protoconid on the lower molars. The present form is smaller than *Paradjidaumo*, and has a narrower lingual length on the upper and buccal length on the lower teeth. I cannot find any close relatives of this form.

Family Heteromyidae Allen and Chapman, 1893

Heteromyid specimens are reasonably common in the Badwater assemblage, but consist almost entirely of isolated teeth. Only in 13 specimens are two or more cheek-teeth in association. Two species are present. Specimens referable to M^1 are clearly able to be separated into two size categories. One, having greater length and width, emphasizes stronger lophs and deeper transverse valley, and the other, smaller type, is characterized by independent cusps and a shallow transverse valley being essentially the same depth as the anteroposterior valley. The second upper molars are also divisible into two size categories, but the separation is not as clearcut. In the first lower molars, the larger size group usually has stronger lophs and lophids than the smaller.

Proheteromys sp. cf. *P. nebraskensis* Wood, 1937 (Fig. 22, Table 9)

Referred specimens.— M^1 : CM 33817–33842; M^2 : CM 17423, CM 17426, CM 17427, CM 33843–33856; M_1 : CM 17425, CM 33857–33879; M_2 : CM 17429, CM 17431, CM 33880–33885.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.— M^1 of this species is considerably larger than that of *Heliscomys* in this fauna. The size of the former is very close to that of *Heliscomys schlaikjeri*, and a little larger than that of *H. tenuiceps*. Morphologically, the present form is very close to *H. schlaikjeri*. As in *H. schlaikjeri*, M^1 is more lophate than are those of the middle Oligocene species of *Heliscomys*, although the principal cusps are still prominent. On most specimens, the protocone and the metacone are of equal size, but the protocone is lower than the paracone even on unworn stage. Several specimens show that whereas the protocone and the hypocone are worn a little, the paracone and the metacone are not worn at all, consequently the paracone becomes much higher than the protocone. The paracone is situated anterobuccal to the protocone so that the tooth is longer and the anterior half of the tooth is considerably wider than the posterior half. The characteristic feature of the anterior half of the tooth being wider is also seen in M_1 of *Heliscomys schlaikjeri*, although Black (1961) did not mention this in his description of his new species. On most specimens, the protocone unites with the paracone only at its base, and these two cusps share a common base, which is raised above the floor of the transverse valley. The notch between the protocone and the paracone is lower than the notch between the hypocone and the metacone. The anterior cingulum is strong and runs lingual from the anterior base of the paracone, but well below the paracone and the protocone. The lingual cingulum exhibits only one large cusp opposite the lingual end of the transverse valley, and shows no evidence of having been divided into two cusps, as in *H. tenuiceps*. This cingular cusp is smaller and lower than the hypocone, but much higher than the anterior cingulum, which unites with the lingual cingular cusp at its anterior base. The cingular cusp connects to the hypocone near its base and the anterior cingulum. The transverse valley is confluent with the valley between the anterior cingulum and the protocone, although the former valley is deeper than the latter, but is blocked by the cingular cusp and the hypocone posterolingually. The hypocone and the metacone are subequal and share a common base, which is high above the floor of the transverse valley. The valley, which separates the metacone from the hypocone, is elongated anteroposteriorly and is blocked posteriorly by the posterior cingulum. The short posterior cingulum runs buccally from the posterobuccal corner of the hypocone to the posterior base of the metacone. With wear, the posterior cingulum is obliterated as in *Heliscomys tenuiceps* and *H. schlaikjeri*.

M^2 of this form is identified based on larger size and more lophate morphology. The morphology of M^2 almost agrees with that of M^1 . On M^2 , the crown is transverse but the anterior half of the tooth is not greatly wider than the posterior half, even though the former is a little wider than the latter. The paracone and the metacone are closer together than in M^1 . The floor of the transverse valley between these buccal cusps is raised so that the valley becomes shallower buccally. The protocone is

Table 9.—Dimensions of teeth of *Proheteromys sp. cf. P. nebraskensis*.

Statistics	M ¹			M ²			M ₁		M ₂	
	L	AW	PW	L	AW	PW	L	W	L	W
N	26	26	26	17	17	17	24	24	8	8
OR	1.08–	1.21–	1.09–	0.87–	1.12–	1.08–	1.11–	1.01–	0.96–	1.07–
	1.27	1.51	1.38	1.00	1.34	1.25	1.30	1.19	1.06	1.20
Mean	1.149	1.416	1.255	0.945	1.210	1.154	1.183	1.117	1.026	1.136
SD	0.050	0.071	0.075	0.038	0.056	0.050	0.047	0.047	0.035	0.047
CV	4.34	5.03	6.01	3.98	4.61	4.35	3.94	4.22	3.37	4.10

lower than the paracone. With wear, the protocone and the hypocone are lowered faster than the paracone and the metacone are. The anterior cingulum is also prominent but lower than the protocone. The lingual cingulum is very thick and tall. No distinct cusps are seen on the lingual cingulum. The lingual cingulum is highest at the point opposite the lingual end of the transverse valley. From there, a ridge descends anterobuccally and is confluent with the anterior cingulum. Posteriorly, the lingual cingulum connects to the hypocone at its lingual base. On one specimen (CM 33844), the lingual cingulum tends to divide into two parts by a small notch, and on one specimen (CM 33846), this cingulum is completely divided into two parts; both parts are conical; the anterior one is small and is anterolingual to the protocone, and the posterior one is larger and is anterolingual to the hypocone. On both specimens (CM 33844, CM 33846), all six cusps are not united by lophes, and the transverse valley and the anteroposterior valley are of the same depth. This situation is very close to that seen in *Heliscomys*.

Lower fourth premolars are not available.

M₁ is square-shaped and somewhat longer than wide. The principal cusps are prominent. Among them, the protoconid and the entoconid are subequal and smaller than both the metaconid and hypoconid. The metaconid is the highest cusp, and the other three cusps are of the same height. After a little wear, the tips of the protoconid and the hypoconid are truncated, whereas the metaconid and the entoconid remain unworn. Then, the difference in height between the buccal cusps and the lingual cusps becomes more emphasized. The differential height in cusps of M₁ is just the mirror image of that of M¹; the buccal cusps are higher than the lingual ones in M₁, whereas the opposite condition holds in M¹. The protoconid and the metaconid share a common base as do the hypoconid and the entoconid. These bases are elevated high above the floor of the transverse valley so that the transverse valley is deeper than the anteroposterior valley. The notch between the protoconid and the metaconid is a little higher than the valley between the anterior cingulum and the protoconid. On most specimens, the anterior cusps do not form a distinct loph. But on several specimens, especially on CM 33859 and CM 33858, the protoconid and the metaconid connect broadly to each other at their base forming the metalophid, although two cusps are still prominent. The anterior cingulum is strong although it is low leaving a transverse valley between it on the one hand and the protoconid and the metaconid on the other. The anterior cingulum connects to the buccal cingulum at the anterobuccal corner of the tooth. No connection between cingula and the protoconid is seen. The protostylid is represented by a thick and elevated ridge, which is merely the posterior continuation of the buccal cingulum. The protostylid

is situated posterobuccal to the protoconid. The hypostylid is more conical and of the same height as the protostylid. The hypostylid connects to the hypoconid at its base. Both the protostylid and the hypostylid are significantly lower than the protoconid and the hypoconid. These stylids are widely separated by a valley, which is confluent with the transverse valley. The degree of development of the posterior cingulum varies. On most specimens, the short posterior cingulum runs buccally from the post robbuccal corner of the entoconid to the posterior base of the hypoconid. A small cingulum connects the hypostylid with the hypoconid at the posterobuccal corner of the tooth, but this cingulum does not connect to the posterior cingulum between the hypoconid and the entoconid, on most specimens. On some (for example, CM 33874), these two cingula unite with each other and surround the posterobuccal base of the hypoconid.

M₂ of this form is identified based on more lophate morphology. The size of M₂ is not significantly larger than that of *Heliscomys* in this fauna so that the difference in size is not applicable for separation into two groups. M₂ is wider than long. The protoconid is subequal to the metaconid and the hypoconid. The entoconid is the smallest among the principal cusps. The protoconid and the metaconid are transversely elongated and united broadly with each other at their base forming the prominent metalophid. The low entoconid unites with the hypoconid at its base, but the hypolophid is not so strongly lophate as in the metalophid. The anterior cingulum is as in M₁. The protostylid is more conical than on M₁. The hypostylid is significantly lower and smaller than the protostylid. On most specimens, the posterior cingulum is absent, but on one specimen (CM 33884), a rudimentary cingulum runs along the posterior bases of the hypoconid and the entoconid.

The morphology of M₃ varies. The protoconid and the metaconid are subequal but the former is a little higher than the latter. The transverse valley is deep separating the metalophid from the hypolophid. The entoconid is reduced in size. The hypoconid is lower than the anterior cusps. The anterior cingulum is present on most specimens, but weak. The protostylid is a small cusp on the buccal cingulum or absent. The hypostylid is greatly reduced if present, or absent. The transverse valley opens buccally. No posterior cingulum is present on all specimens available.

Discussion.—The upper dentition of this form is very close to that of *Heliscomys schlaikjeri*. The holotype of *H. schlaikjeri* is worn a little so that it is rather difficult to compare it precisely with the present form. The size is almost the same. That the molars are more lophate and the anterior half of M¹

Table 10.—Dimensions of teeth of *Heliscomys* sp. cf. *H. vetus*.

Statistics	P ⁴		M ¹			M ²			P ₄		M ₁		M ₂	
	L	W	L	AW	PW	L	AW	PW	L	W	L	W	L	W
N	27	27	27	27	27	15	15	15	9	9	17	17	15	15
OR	0.64– 0.91	0.66– 0.93	0.74– 0.94	0.96– 1.16	0.92– 1.11	0.72– 0.92	0.89– 1.10	0.86– 1.07	0.48– 0.73	0.52– 0.72	0.88– 1.07	0.89– 1.08	0.85– 1.00	0.94– 1.14
Mean	0.739	0.807	0.859	1.046	0.990	0.806	0.994	0.961	0.623	0.634	0.970	0.967	0.923	1.004
SD	0.068	0.078	0.053	0.061	0.055	0.062	0.063	0.057	0.073	0.069	0.062	0.062	0.055	0.056
CV	9.17	9.69	6.21	5.86	5.53	7.66	6.29	5.93	11.79	10.87	6.36	6.39	5.94	5.62

is wider than the latter is clearly shared in both forms. I have not found any reason to separate the present form from *H. schlaikjeri*. The present form and *H. schlaikjeri* differ from *H. tenuiceps* of the middle Oligocene in having a wider anterior half of M¹. The size of *H. tenuiceps* is a little smaller than that of both the present form and *H. schlaikjeri*. *Heliscomys tenuiceps* and *H. schlaikjeri*, which are known only from the upper dentition may eventually be removed from the genus. This problem will be discussed below.

The most remarkable feature seen in the upper dentition of the present form is the presence of the smaller protocone than the paracone. The holotype of *H. schlaikjeri* is worn and the protocone unites with the paracone with wear on this specimen. It is impossible to tell whether *H. schlaikjeri* might have had the smaller protocone on M¹ or not. The presence of a small protocone on the upper molars is unusual among heteromyids. The morphology of the smaller protocone on M¹ is reflected in the morphology of M¹, too.

On M₁, the protoconid is smaller than the paraconid. The size and general morphology except for the smaller protoconid are very close to *Proheteromys nebraskensis*. The holotype of *P. nebraskensis* is worn. The paratype established by Wood (1937) is an almost unworn specimen. Wood stated (1937: 215) that "(In *P. nebraskensis*) The protostylid of the molars is separate from the cingulum when unworn, and it far to the rear. The protoconid and metaconid are connected by a cingulum along their anterior margin." All the specimens at hand referable to M₁ have the anterior cingulum, which is clearly separated from the protoconid and the metaconid. On most specimens at hand, the protostylid is connected to the buccal cingulum, but on one specimen (CM 33876), the protostylid is clearly separated from the cingulum. The degree of the development of the anterior cingulum usually varies among het-

eromyids. I believe the strong or weak development of the anterior cingulum is not a good criterion for separating species.

Although the present form has a small protoconid on M₁, I believe the morphology of the present form is not clearly separable from *Proheteromys nebraskensis*. The present form is best described as *Proheteromys* sp. cf. *P. nebraskensis*. And, I consider *Heliscomys schlaikjeri* to be conspecific with the present form.

Heliscomys sp. cf. *H. vetus* Cope, 1873 (Fig. 23, Table 10)

Referred specimens.—P⁴-M¹: CM 17421, CM 33886–33889; P⁴-M²: CM 17091, CM 19879, KU 16626; P⁴-M³: CM 19787; P⁴: CM 19790, CM 33890–33906; M¹-M²: CM 33907; M¹: CM 17092, CM 33908–33923; M²: CM 33924–33935; P₄-M₂: CM 19786; P₄-M₃: CM 33936; P₄: KU 16627, CM 17432, CM 19788, CM 33937–33940; M₁: CM 17424, CM 33941–33954; M₂-M₃: CM 33955; M₂: CM 17430, CM 33956–33966.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Description.—Nine upper jaw fragments with P⁴ and M¹ are referable to *Heliscomys*. The size, both length and width, varies, even among these specimens. Materials referable to P⁴ are not able to be separated into two groups on the basis of size. All the specimens referable to heteromyid P⁴ are described below as *Heliscomys*, but surely some of them must be referred to *Proheteromys*. At present, I cannot tell morphological differences between the upper fourth premolars of *Heliscomys* and *Proheteromys* in the Oligocene.

P⁴ shows a pattern of a large, anteriorly placed protocone and a three-cusped metaloph. The protocone and the hypocone are subequal and conical on most specimens. The metacone is a little smaller than the hypocone. On several specimens, the protocone is smaller than the hypocone and subequal to the metacone. The degree of the development of the entostyle varies; on some specimens, the entostyle is a small, low cusp; on some, it is a rudimentary cusp on the lingual base of the hypocone; on two specimens (CM 33891, CM 33897), the entostyle is not seen at all and the tooth has three cusps, one on the anterior loph and two cusps on the posterior loph. Galbreath stated (1953:63) that there seems to be a definite correlation between the size of the premolar and the amount of reduction of the entostyle. In the present fauna, no such correlation is seen; the cuspidate ento-

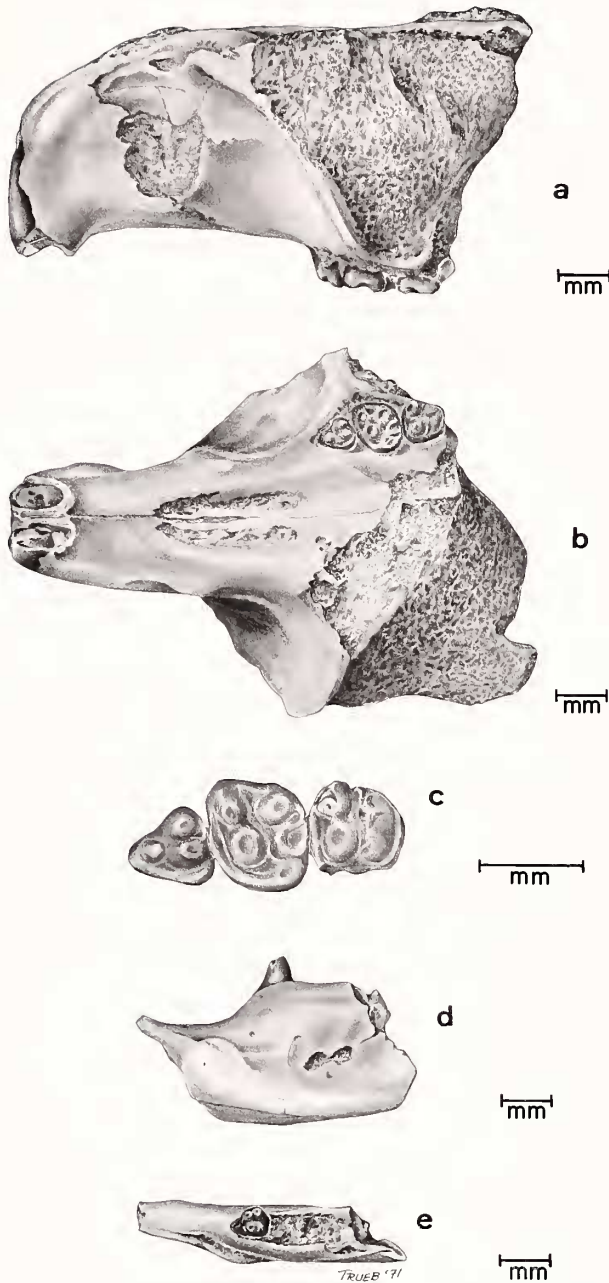


Fig. 23a-e.—*Heliscomys* sp. cf. *H. vetus*. a: KU 16626, skull with left P^4 - M^2 , lateral view. b: same, ventral view. c: same, crown view of teeth. d: KU 16627, left lower jaw with P_4 , lateral view. e: same, crown view.

style is seen on both large and small teeth, and the rudimentary entostyle is also observed on both types. Most specimens show a tendency towards the formation of transverse lophs. The hypocone and the metacone share a common base and the valley separating these cusps is not deep. These two cusps are not discrete and with further wear they lose their individual identity. On one specimen (CM 17091), however, no tendency towards

the formation of a loph is seen and the cusps are discrete. Even on this specimen, the entostyle is situated anterolingual to the hypocone as in another specimen. With wear, the metaloph and the entostyle give rise to an incipient J-pattern. The entostyle, if present, does not connect to the protocone. On some specimens, there is a small cusp at the anterobuccal base of the protocone. On others, no cusp is seen there.

The size of M^1 is considerably smaller than that of *Proheteromys*. The morphology of M^1 greatly varies. Some of them are not separable morphologically except by size from the corresponding tooth of *Proheteromys*. The principal cusps are subequal. The transverse valley is a little deeper than the anteroposterior valley. Great morphological variation is seen in the structure of the lingual cingulum. On some specimens (for example, CM 33907), the small but distinct protostyle is present just lingual to the protocone. It is separated from the anterior cingulum by a small notch, and from the entostyle by the transverse valley. In this form, the transverse valley is opened lingually. The entostyle is lingual and a little anterad to the hypocone, and only slightly smaller than the hypocone and the metacone. On one specimen (CM 33918), a small cusp is present at the anterolingual corner of the tooth and posterior to it another smaller cusp is present just lingual to the protocone. The entostyle is rather prominent. These three cusps form the lingual border of the tooth so that the transverse valley is not opened lingually. One specimen (CM 33917) shows the entostyle shifted more anteriorly closer to the small protostyle and it tends to block the transverse valley lingually. On this specimen, the entostyle is separated from the protostyle by a small notch, which lies little above the floor of the transverse valley. On other specimens (CM 33910, CM 33914), the entostyle is shifted further anteriorly just lingual to the transverse valley. From the entostyle, a thick ridge descends anteriorly and is confluent with the anterior cingulum. In this situation, it is impossible to distinguish either a protostyle or entostyle in this ridge. Thus the central valley is completely blocked by this lingual cusp. This morphology agrees exactly with that seen in *Proheteromys*. The protocone is of the same size as the paracone on M^1 . Otherwise, morphologically this tooth is not easily separated from the corresponding tooth of *Proheteromys*.

M^2 agrees in most respects with the patterns seen on M^1 , and the morphological variation among individuals seems to be reduced. The morphological differences from the pattern seen in M^1 are in the construction of the lingual cingulum and the styles. On M^2 there is a high ridge which closes the transverse valley at the lingual margin. In this ridge it is impossible to distinguish either a protostyle or entostyle. On several specimens (CM 33930, CM 33931, CM 33933), a small notch lingual to the transverse valley divides the lingual cingulum into two portions. The notch is not deep and both parts of the cingulum do not form any cusp. On all specimens, the connection of the lingual cingulum to the hypocone is stronger and at a higher level than is the connection to the anterior cingulum.

The mandible is rather slender. The diastema is short and the diastemal depression is shallow. The anterior end of the masseteric fossa is swollen and makes the jaw appear massive at this point. The mental foramen lies anterior to P_4 , and almost on the dorsal surface of the mandible.

Nine specimens referable to heteromyid P_4 are available. They cannot be separated into two groups only based on size. Two jaw fragments with at least P_4 and M_1 are available, of which lower first molars are referable to *Heliscomys*. All the materials

of P_4 in this fauna will be described below as *Heliscomys* but the possibility that some of them should be referred to *Proheteromys* is not ruled out. Eight specimens of P_4 out of nine are quadricuspsate. On most specimens, the metaconid, hypoconid, and entoconid are of equal size and height. On some specimens (CM 17432, CM 33938), the metaconid is the smallest and the hypoconid is the largest among these three cusps. Seven specimens out of eight quadricuspsate lower fourth premolars have the tiny protoconid, which is significantly smaller and lower than the metaconid and situated on the anterobuccal corner of the tooth. On six specimens out of these seven, the protoconid is separated by small notches from both the metaconid and the hypoconid. On one specimen (CM 33936), the protoconid is united with the hypoconid by a short ridge, but separated by the anteroposterior valley from the metaconid. On one specimen (CM 33903), the protoconid is much larger than on the other specimens although it is a little smaller than the metaconid. On this specimen, the protoconid is separated from both the metaconid and hypoconid. On all eight specimens there is an indication of a hypoconulid between the hypoconid and entoconid at the posterior margin of the tooth. One specimen (CM 33937) is tricuspsate. On this, the metaconid is situated just anterad to the midline between the hypoconid and entoconid. The hypoconid is the largest and the other two cusps are of equal size. No shelf is seen on the anteroexternal corner of the tooth. No indication of a hypoconulid is seen.

The structure of M_1 and M_2 is very close to those of *Heliscomys vetus* described by Galbreath (1953) from the middle Oligocene of Colorado. The pattern of lower molars is that of four well-developed primary cusps more or less bordered on three sides by low cingula, which develop cusps. The teeth are cuspsate rather than lophate, but with wear, lophs tend to form. The protostylid is larger than the hypostylid, but smaller and lower than the protoconid. On most specimens, the anterior cingulum is united to the anterolingual angle of the protoconid by a weak crest. The connection of the anterior part of the buccal cingulum to the protostylid varies; these two structures are separated by a notch, or where the cingulum is weak, it may unite to the protostylid without any notch between them. The transverse valley separates the protostylid from the hypostylid. Posterior to the hypostylid the cingulum varies from strong to weak, on some specimens extending across the posterior face of the entoconid and in others fading out on the posterior face of the hypoconid.

M_3 is composed of four well-developed primary cusps. Stylids are reduced. The hypoconid is somewhat reduced and is the smallest of the primary cusps. The anterior cingulum is weak on the face of the metaconid, absent at the midline of the anterior border of the tooth, and stronger on the anterior and buccal faces of the protoconid. The posterior cingulum is greatly reduced; on two specimens, it is absent completely, but on one specimen a small shelf lies on the posterior border between the hypoconid and the entoconid.

Discussion.—In size these specimens appear to be slightly larger than the mean for the middle Oligocene populations from Colorado discussed by Galbreath (1953:65). However, most of them fall well within the size range given for the Colorado specimens. Also, the structure of the cheek teeth and the variation seen in the present material co-

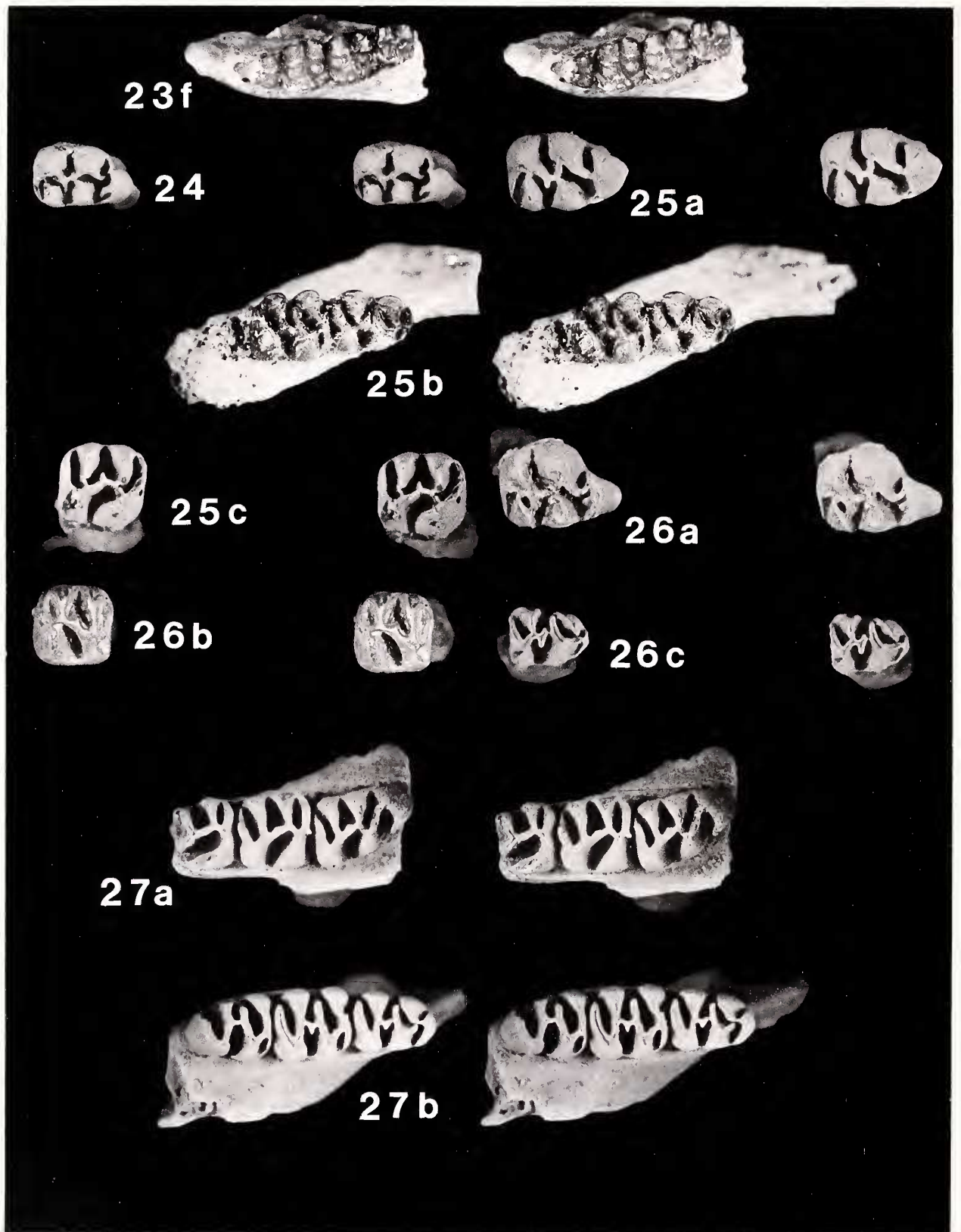
incide well with those which are observed in the earlier Colorado populations. The same situation was reported by Black (1965:45) for the early Oligocene population.

It must be noted that the morphological variation observed in the middle Oligocene populations is duplicated in the late Oligocene Badwater fauna, and also in the early Oligocene Pipestone material (Black, 1965); in the late Oligocene Badwater population, the three-cusped condition of P_4 as well as the four-cusped condition are both represented. Both the three-cusped and four-cusped condition persisted from the early Oligocene through the late Oligocene. Wood (1939:560), Wilson (1949b:115), Galbreath (1953:65) and Black (1965:45) have all suggested that the four-cusped condition of P_4 was primitive and that the three-cusped condition represented reduction from that more primitive stage. This would certainly seem the most probable evolutionary pattern in *Heliscomys*. In the late Oligocene population, the three-cusped condition is seen on only one specimen out of nine of P_4 . Although the sample size is not big enough to determine definitely, it would appear that the selection was favoring the four-cusped condition and the reduction or eventual loss of the protoconid on P_4 was under somewhat strong selective pressure through the Oligocene Epoch. If this were the case, this variation suggests that *Heliscomys* was ancestral to *Proheteromys*.

AFFINITIES OF THE OLIGOCENE HETEROMYIDS

The Oligocene and the early Miocene heteromyids having the three-cusped P_4 and more cuspsate molars tend to be assigned to *Heliscomys*, and those having the four-cusped P_4 and more lophate molars to *Proheteromys*. The morphological variation seen in P_4 of *Heliscomys vetus* creates a problems for the taxonomic assignment.

Heliscomys vetus has the three-cusped as well as the four-cusped P_4 . The difference in morphology of P_4 is not a good criterion any more for the separation of *Heliscomys* from *Proheteromys*. It seems to me that the best criterion for separation of these genera is the degree of development of lophs and lophids on molars; *Proheteromys* is more lophate and *Heliscomys* is more cuspsate. If this is true, *Heliscomys tenuiceps* and *H. schlaikjeri* must be removed from the genus *Heliscomys* and referred to *Proheteromys*, because both forms have clearly lophate crown patterns.



On M_1 of both forms just mentioned, the lingual cingulum is high enough to block the transverse valley lingually. In *Heliscomys vetus*, M_1 has a moderate lingual cingulum having two styles, which are separated from each other by the continuation of the transverse valley. So the transverse valley is open lingually on this form. But the morphology of M_1 of *H. vetus* shows a considerable range of variation as stated in the description. From the "normal" situation of the lingual cingulum, it tends to unite two styles into single style and form a high ridge to block the transverse valley lingually. In an undescribed collection many specimens referable to *Heliscomys vetus* have exactly the same morphological variation. The variant having the strong lingual cingulum with a single style blocking the transverse valley is not easily separated from *Heliscomys tenuiceps* morphologically other than size. *H. tenuiceps* and *H. schlaikjeri* are larger than *H. vetus*. This suggests that *H. vetus* should have given rise to *H. schlaikjeri* via *Proheteromys nebraskensis*-stage in the late Oligocene.

Family Cricetidae Rochebrune, 1883

Eumys parvidens Wood, 1937

(Fig. 24, Table 11)

Referred specimen.— M_1 : CM 32939.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.— M_1 is square-shaped, except for the anterocone. The tooth is smaller than that of *Eumys elegans*. The anterocone is large and situated on the buccal side of the tooth. The anterior cingulum is very short and curves posterobuccally; the posterobuccal end connects to the anterior arm of the protocone. A short ridge runs posterobuccally from the summit of the anterocone but does not reach the buccal border of the tooth. No connection between the anterocone and the paracone is seen so that a narrow valley runs buccally between these cusps. The protocone is stout and somewhat elongated anteroposteriorly. The anterior arm of the protocone descends anterobuccally from the anterobuccal corner of the protocone and turns anterolingually connecting to the anterior cingulum. A small valley is seen in front of the protocone. This valley is blocked anterolingually by a thin ridge forming the anterolingual corner of the tooth. The paracone is round and as high as the protocone, which is slightly higher than the anterocone. The paracone is situated buccal to the posterior half of the protocone. The mure is a thin ridge descending posterobuccally from the posterobuccal corner of the

protocone turning posterolingually from the lingual extremity of the mesoloph. The protolophule II originates at the posterolingual corner of the paracone and runs lingually but slightly posteriorly. This connects to the mure at the middle of it between the posterobuccal corner of the protocone and the mesoloph. The mesoloph is short but distinct. This merges to the anterior border of the metacone at the midpoint of it so that a narrow valley runs buccally between the paracone and the mesoloph. The hypocone is stout and as high as the protocone forming the posterolingual corner of the tooth. A deep valley runs lingually between the protocone and the hypocone but is blocked lingually by a tiny entostyle. The metacone is somewhat compressed anteroposteriorly, and is situated just posterior to the paracone and buccal to the hypocone. It is almost as high as the paracone. The metalophule II runs almost lingually from the posterolingual corner of the metacone and connects to the body of the stout hypocone. A valley is present between the metacone and the hypocone but blocked by both the mesoloph anteriorly and the metalophule II posteriorly. The posterior cingulum runs buccally behind the metacone and connects to the posterobuccal corner of the metacone so that the valley just behind the metacone does not open buccally. All the ridges are very low.

Discussion.—This taxon is represented by a single tooth. The tooth is characterized by well-defined cusps and low ridges. The structure of the tooth differs from that seen in *Eumys elegans* in having the protocone and the hypocone essentially as high as the paracone and the metacone, anteroposteriorly elongated protocone, and low ridges. These characteristic features are less specialized than those of *Eumys elegans*, which shows more developed ridges. I agree with Wood (1937) who stated, "In general, this form (*E. parvidens*) has a primitive *Eumys* pattern on a small scale."

Eumys elegans Leidy, 1856

(Fig. 25, Table 11)

Referred specimens.— M^1 : CM 32918–32921, CM 32940; M^2 : CM 32922, CM 32923, CM 33109, CM 33110, CM 33112; M^3 : CM 32926–32934; M_1 - M_2 : CM 17086; M_1 : CM 32900–32905, CM 32907, CM 32908, CM 32910, CM 32911, CM 32935, CM 32936; M_2 : CM 32912–32917, CM 32937, CM 33113; M_3 : CM 32938.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—On M^1 , the anterocone is prominent and triangular in shape, with the apex leaning anteriorly. The anteroloph, or the anterior cingulum forming the base of the trigon of the anterocone, is transverse. The anterior arm of the protocone connects to the anterocone at the midpoint of the base of the triangle in most specimens. The paracone and the metacone are

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Fig. 23f.—*Heliscomys* sp. cf. *H. vetus* (continued). f: CM 33936, left P_4 - M_3 . $\times 15$. Fig. 24.—*Eumys parvidens*. CM 32939, left M^1 . $\times 8$. Fig. 25.—*Eumys elegans*. a: CM 32919, left M^1 . $\times 8$. b: CM 17086, right M_1 - M_2 . $\times 6$. c: CM 32922, right M^2 . $\times 8$. Fig. 26.—*Eumys brachyodus*. a: CM 17412, left M^1 . b: CM 32925, left M^2 . c: CM 32909, right M_1 . $\times 8$. Fig. 27.—*Eumys*. sp. cf. *E. planidens*. a: CM 32941, right M^1 - M^3 . b: CM 19799, right M_1 - M_3 . $\times 8$.

Table 11.—Dimensions of teeth of *Eumys parvidens*, *Eumys elegans*, and *Eumys brachyodus*.

Statistics	M ¹		M ²		M ³		M ₁		M ₂		M ₃	
	L	W	L	W	L	W	L	W	L	W	L	W
<i>Eumys parvidens</i>												
N	1	1										
OR	2.40	1.45										
<i>Eumys brachyodus</i>												
N	1	1	3	3			2	2				
OR	2.89	1.89	1.82– 1.91	1.83– 1.93			1.86– 2.13	1.41– 1.68				
Mean			1.860	1.880								
<i>Eumys elegans</i>												
N	2	2	3	3	5	5	10	10	7	7	1	1
OR	2.84– 2.98	1.70– 2.02	2.03– 2.07	1.77– 2.03	1.44– 1.67	1.51– 1.80	2.09– 2.70	1.51– 2.07	2.07– 2.31	1.71– 2.01	1.96	1.78
Mean			2.050	1.880	1.568	1.660	2.293	1.715	2.186	1.871		
SD							0.171	0.178	0.101	0.111		
CV							7.45	10.37	4.60	5.91		

subequal but the latter is somewhat elongated transversely. Both are slightly taller than the protocone and the hypocone. The protocone is compressed posteriorly so that the posterior wall is vertical, whereas the anterior wall descends gently. From the summit of the protocone two ridges originate—one runs anterobuccally forming the anterior arm of the protocone, and the other runs almost transversely forming the protolophule II and connects to the paracone. The paracone is situated just buccal to the protocone. The mure is very short and runs anteroposteriorly. This connects to the protolophule II near the lingual corner of the paracone. The metaloph is very short but distinct. On most specimens the metaloph is situated between the paracone and the metacone, but on some (for example, CM 32920) it is closely related to the metacone though it does not unite to the latter. The hypocone is stout forming the posterolingual corner of the tooth. The anterior wall of the hypocone descends gently towards the posterior base of the protocone so that the valley between the protocone and the hypocone is very narrow in contrast to the wide valley in *Eumys planidens*. From the summit of the hypocone two ridges originate—one passes anterobuccally forming the anterior arm of the hypocone and the other runs buccally forming the posterior cingulum. The metalophule unites to the anterior arm of the hypocone just anterior to the hypocone. Because of the transversely elongated metacone, the metalophule is very short. All the ridges are rather thick and high above the crown of the tooth but they do not rise to the summits of the cusps.

M² is longer than wide. All the cones are compressed anteroposteriorly but are still well defined. The paracone and the metacone are taller than both the protocone and the hypocone. The protocone is elongated posterolingually. The anterior arm of the protocone forms the anterior cingulum so that no lingual part of the anterior arm of the protocone runs posterobuccally. The protolophule II is short and the protolophule I is not present. A narrow valley is present between the paracone and the anterior cingulum. The mure runs anteroposteriorly but is very short.

The hypocone is smaller than in M¹. The anterior base of the hypocone extends anterobuccally forming the base of the anterior arm of the hypocone. The valley between the protocone and the hypocone runs posterolingually and is very narrow. This valley becomes deeper lingually. A short mesoloph is present between the paracone and the metacone. The metacone is elongated transversely and the metalophule is but a lingual extension of the metacone. The summit of the hypocone is shifted more lingually than in M¹ so that the valleys between the posterior cingulum and the metacone and the metacone and the mesoloph are longer transversely than in M¹.

M³ is very small. The protocone extends posteriorly forming the lingual border of the tooth. The paracone is the tallest and the metacone is as high as the protocone. All the ridges rise to almost the same level of the protocone and the paracone. The bases of all the ridges and cusps are broad so that all the valleys between ridges and cusps are rather narrow. The protolophule II runs posterolingually from the lingual corner of the paracone.

M₁ is long and narrows anteriorly. The anteroconid is elongated transversely and situated on the front of the tooth. The anterior arm of the protoconid runs anterolingually from the summit of the protoconid but soon turns anteriorly and joins the anteroconid just buccal to the midpoint of the tooth. No direct connection between the anteroconid and the metaconid is present on most specimens, but there is considerable variation in morphology; some have no connection of the anterior arm of the protoconid with the anteroconid (CM 32901); some have a connection between the anteroconid and the metaconid (CM 32900). The metaconid and the entoconid are subequal and taller than both the protoconid and the hypoconid. The lingual wall of the metaconid is curved lingually. The anterior and the posterior walls of the metaconid are very steep leaving a sharp crest between them, which forms the metalophulid I. The posterior protoconid arm runs posterolingually and then turns buccally. It connects with the posterior corner of the metaconid so that a basin without outlet is formed between the protoconid and the

metaconid on most specimens. On some specimens (CM 32900), the posterior arm of the protoconid is closely related to the metaconid but does not connect to it. The ectolophid runs almost anteroposteriorly and is lower in position than the posterior arm of the protoconid. The mesolophid is distinct but shorter than the posterior arm of the protoconid on most specimens. On one specimen (CM 32935), the mesolophid is clearly longer than the posterior arm of the protoconid but does not reach the lingual border of the tooth. The hypoconid is stout. The anterior arm of the hypoconid is short. The valley between the protoconid and the hypoconid is broad lingually but becomes narrower buccally. The posterior cingulum does not connect to the entoconid.

M_2 is slightly longer than wide. All the cusps are somewhat compressed anteroposteriorly. The metaconid and the entoconid are taller than the protoconid and the hypoconid. All the ridges rise to almost the same level as the protoconid and the hypoconid. The anterior cingulum is complete buccally and lingually. The protoconid and the metaconid unite to the anterior cingulum separately. The posterior arm of the protoconid extends posterolingually. On some specimens (CM 32937), it runs between the metaconid and the entoconid, on some (CM 32912) it is closely related to the metaconid but does not reach the lingual border of the tooth, and on some (CM 32914) it reaches nearly the lingual border of the tooth and connects to the metaconid on its posterior base. The lingual portion of the mesolophid is not present. The buccal portion of it is clearly defined but short on most specimens. Some specimens (CM 17086) do not have the buccal portion of the mesolophid. The valley between the protoconid and the hypoconid is excavated posteriorly and narrow buccally. The ectolophid runs almost anteroposteriorly. The hypolophid I runs transversely but slightly anteriorly. The anterior arm of the hypoconid runs anterolingually from the summit of the hypoconid. The posterior cingulum is strong.

On M_3 , the general morphology agrees with that of M_2 . The posterior protoconid arm reaches the lingual border of the tooth. The entoconid is greatly reduced. It forms a thin ridge like the posterior arm of the protoconid and runs parallel with the latter. The hypoconid is reduced and the valley between the protoconid and the hypoconid is deep. The posterior cingulum is not as strong as in M_2 . The reduced hypoconid and entoconid and the weak posterior cingulum make the tooth narrower posteriorly.

Discussion.—The teeth of this species show a wide range of morphological variation. Based on the variable morphology, I believe, too many species of *Eumys* have been described. The type species of *Eumys* is *E. elegans*. The characteristic features of this species as listed by Wood (1937) are subequal buccal and lingual portions of the anterior cingulum, long posterior arm of the protoconid being free from both the metaconid and the entoconid, no lingual portion and weak buccal portion of the mesolophid, and reduced hypoconid. Most of the present specimens referable to M_2 show exactly the same features. They surely belong to *E. elegans*.

One specimen (M_1 , CM 32935) has a longer mesolophid than the posterior arm of the protoconid. This characteristic feature is seen in the European

cricetid, *Cricetodon*. Wood (1937) described a similar form from the Upper Oreodon Beds of Nebraska under the name of *Cricetodon nebraskensis*. The present form is very close to the holotype of *C. nebraskensis* but all the morphology except the long mesolophid agrees with that of *Eumys elegans*. I am not confident to separate this form from *E. elegans*.

Martin (1972) placed *Eumys obliquidens*, *E. cricetodontoides*, *E. latidens*, *E. spokauensis* and *Cricetodon nebraskensis* into the synonymy of *E. elegans*.

Specific characters, especially of M_2 , of each named species are summarized as follows: *Eumys obliquidens*—the posterior arm of the protoconid runs posteriomesial and unites with the entoconid; *E. cricetodontoides*—lingual part of the anterior cingulum is long, posterior arm of the protoconid long but not united with metaconid, mesolophid short but distinct; *E. latidens*—lingual part of the anterior cingulum is half as long as the buccal part, posterior arm of the protoconid is not long and not united with the metaconid, no mesolophid; *E. spokauensis*—lingual portion of the anterior cingulum obsolete, posterior arm of the protoconid closely applied to entoconid, no mesolophid; *Cricetodon nebraskensis*—longer mesolophid than the posterior arm of the protoconid.

When Galbreath (1953) discussed the variation among the eumyine rodents, he stated that presence or absence of cingula are good but strength of development of cingula are poor criteria to evaluate the characters of the teeth. I agree with him. As for the present specimens referable to M_2 , the buccal part of anterior cingulum is almost always present and extends along the buccal half of the tooth. Although the lingual part of it is usually present, the degree of development varies; it is long and extends to the lingual margin of the front of the tooth on some specimens, but it is short and half or less as long as the buccal part on the others. The degree of development of the lingual portion of the anterior cingulum used as the key to separate *E. latidens* from *E. cricetodontoides* by White (1954) is of no value. Various degrees of development of the cingulum are seen within the specific variation of *E. elegans*.

On most of the present specimens of M_2 , a short buccal portion of the mesolophid is present. On one specimen (CM 17086), a tiny mesoconid is seen on the middle of the ectolophid but the buccal portion of the mesolophid is totally absent. The presence

or absence of short buccal portion of the mesolophid seems to me to be of no great value for taxonomic evaluation for species of *Eumys*.

I do not find any reasons to separate *E. cricetodontoides* from *E. elegans*. As I described above, CM 32912 is an *E. latidens*-type form and CM 32935 is a *Cricetodon nebraskensis*-type form. I believe they are variants of *E. elegans* and I cannot find any reasons to separate them from *E. elegans*. *E. obliquidens* and *E. spokaneensis* are characterized by having the posterior protoconid arm closely applied to or united with the entoconid. No specimens in the present fauna show this characteristic feature. Based on the present Badwater Oligocene fauna, I agree with Martin (1972) in part to place *E. cricetodontoides*, *E. latidens*, and *Cricetodon nebraskensis* into the synonymy of *E. elegans*.

Eumys brachyodus Wood, 1937

(Fig. 26, Table 11)

Referred specimens.—M¹: CM 17412; M²: CM 32924, CM 32925, CM 33096–33098; CM 33111; M³: CM 33099, CM 33100; M₁: CM 32906, CM 32909.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Description.—The general morphology of M¹ almost agrees with the corresponding tooth of *Eumys elegans*. The present form differs from *E. elegans* in having a wider crown and the reduced anterocone. The crown is compressed anteroposteriorly. The anterocone is reduced. The anterior arm of the protocone unites with the anteroloph near its lingual margin, and from the summit of the anterocone one short ridge descends posterobuccally but this ridge does not connect to the paracone. The protocone leans buccally so that the protocone occupies the lingual half of the anterior part of the crown. The valley between the protocone and the hypocone is lying transversely and its anterobuccal extremity is very close to the lingual tip of the paracone. That valley extends buccal to the middle of the crown.

M² is wider than that of *Eumys elegans*. The width is almost subequal to the length, but on most specimens the length is little greater than the width. On one specimen (CM 32925), the crown is clearly wider than long. The lingual half of the anterior cingulum is not present on all specimens available. The valley between the protocone and the hypocone is long transversely. The mesoloph is very short.

Discussion.—The size of the present form is very close to that of *Eumys elegans*. The teeth of *E. brachyodus* is short and wider than *E. elegans*. Moreover, in *E. brachyodus*, the lingual half of the anterior cingulum is not present and the mesoloph is extremely short on M². The present form shows these morphology. The remainder of morphology of *E. brachyodus* is almost exactly the same as *E. elegans*. I believe that *Eumys brachyodus* has a common ancestry with *Eumys elegans*.

Eumys sp. cf. *E. planidens* Wilson, 1949a

(Fig. 17, Table 12)

Referred specimens.—M¹-M²: CM 19795, CM 32943, CM 32944; M¹-M³: CM 17088, CM 32941; M¹: CM 17413, CM 32946–32980, CM 33061, CM 33093, CM 33095, CM 33114; M²-M³: CM 19713, CM 32942, CM 32945; M²: 33003, CM 33062, CM 33094, CM 33115, CM 33116; M³: CM 17411, CM 17414, CM 33004–33026; M₁-M₃: CM 19798, CM 19799; M₁: CM 17416–17419, CM 33028–33037, CM 33063–33078, CM 33117, CM 33118; M₂: CM 17420, CM 33038–33060, CM 33079–33091, CM 33119.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—On M¹, the anterocone is large. It is nearly two-thirds as wide as the tooth at the paracone-protocone line. All the cones except the anterocone are compressed anteroposteriorly and together with all the ridges rise to a nearly common plane. All the ridges are thin. The anterior protocone arm runs anterobuccally to reach the anterocone buccal at the midline. Between the anterior protocone arm and the anterior cingulum, a deep valley opens lingually. The posterior protocone arm runs posterobuccally but is short. It connects to the mure and the protolophule buccal to the paracone. Between the paracone and the anterior protocone arm, a valley opens deeply and runs anterobuccally. The protolophule is just a lingual extension of the paracone. No mesocone is seen, but a tiny buccal projection is present on the middle of the mure. The metalophule is also just a lingual extension of the metacone. The protolophule and the metalophule run parallel to each other and open into a wide valley lingually. This valley becomes narrower buccally because of the widened bases of the paracone and the metacone. The hypocone is also compressed anteroposteriorly so that the valley between the protocone and the hypocone is wide and opens lingually. The posterior cingulum located buccally from the hypocone forms a deep valley between it and the metalophule. This valley opens buccally. The tooth is characterized by deep valleys and thin ridges.

On M², the protocone is greatly compressed anteroposteriorly forming a high, thin ridge. The length of the protocone is almost half the width of the tooth. The anterior arm is short, half as long as the posterior protocone arm. The anterior arm merges into the buccal part of the anterior cingulum, which reaches to the anterobuccal margin of the tooth. No lingual anterior cingulum is seen. The paracone and the metacone are more compressed anteroposteriorly than on M¹ forming thin ridges running transversely. The valley between the paracone and the metacone opens more widely than on M¹, but is a little narrower buccally. The mure runs posterolingually and is situated in the center of the tooth. The hypocone is also more compressed than on M¹. The valley between the protocone and the hypocone is wide and opens posterolingually. The posterior cingulum runs from the hypocone buccally and slightly posteriorly. This cingulum is short, almost half as long as the metacone-metalophule. This cingulum does not form a wall on a posterobuccal corner of the tooth so that the valley between it and the metacone is wider than on M¹.

On M³, the lingual portion of the anterior cingulum and the protocone form the anterior border of the tooth. The lingual margin of the protocone extends posteriorly and reaches to nearly the posterolingual corner of the tooth. A hypocone does not occur on this tooth but the ridge correlated to the anterior arm

Table 12.—*Dimensions of teeth of Eumys sp. cf. E. planidens.*

Statistics	M ¹		M ²		M ³		M ₁		M ₂		M ₃	
	L	W	L	W	L	W	L	W	L	W	L	W
N	16	16	11	1	13	13	16	16	12	12	4	4
OR	2.27– 2.96	1.57– 2.09	1.86– 2.18	1.64– 2.18	1.53– 1.88	1.68– 1.93	1.87– 2.35	1.30– 1.78	1.85– 2.27	1.75– 2.08	2.24– 2.40	1.74– 2.11
Mean	2.734	1.884	1.989	1.957	1.756	1.822	2.156	1.568	2.084	1.942	2.338	1.920
SD	0.176	0.126	0.107	0.132	0.102	0.070	0.153	0.131	0.135	0.105		
CV	6.42	6.69	5.37	6.74	5.80	3.83	7.10	8.33	6.50	5.43		

of the hypocone remains forming a posterior extension of the mure. The valley between the protocone on the one hand, and the mure and the anterior arm of the hypocone on the other, forms a wider, anteroposterior trench. No posterior cingulum is seen. The paracone and the metacone are thinner transversely than on M².

M₁ is longer than wide. The anteroconid is elongated transversely. The connections of the anteroconid with the anterior arms of the protoconid and the metaconid vary. On most specimens, the anterior arm of the protoconid runs anterolingually and unites with the anterior arm of the metaconid, which runs almost transversely. Then the former turns anteriorly and connects to the anteroconid at its midpoint. The buccal part of the anterior cingulum is as long as the lingual part. On some specimens (CM 33029), the anterior arm of the protoconid joins the anteroconid more lingually so that the lingual part of the anterior cingulum is much shorter. Some specimens (CM 19799) show no connection between the anterior arms of the protoconid and the metaconid on an unworn stage, and only the anterior arm of the metaconid connects to the anteroconid on its lingual side so that the lingual part of the anterior cingulum is short. One specimen (CM 17416) shows peculiar features—the anteroconid on its buccal side; the lingual part of the anterior cingulum extends posteriorly and joins the anterior arm of the metaconid; no connection between the anterior arms of the protoconid and the metaconid at all. All the ridges and the anteroconid rise to the same level as the protoconid and the hypoconid. The metaconid and the entoconid are slightly taller than both the protoconid and the hypoconid. The posterior arm of the protoconid extends lingually but does not reach the lingual border of the tooth. This arm connects to the posterior margin of the metaconid at the base. A mesoconid is tiny and has a small buccal projection. No mesolophid is present. The entoconid is triangular in shape. The metalophid II is transverse. The valley between the entoconid and the posterior arm of the protoconid becomes narrower lingually but opens there. The hypoconid is compressed anteroposteriorly and forms a wide valley between it and the protoconid. The valley between them becomes narrower buccally because the buccal margin of the protoconid extends slightly posteriorly. The valley opens buccally. The posterior cingulum runs posterolingually to near the lingual border of the tooth forming a long valley between it and the entoconid. This cingulum does not connect to the entoconid.

M₂ has no lingual part of the anterior cingulum. The anterior wall of the metaconid has a small excavation indicating the original presence of a valley between the metaconid and an ancestral lingual anterior cingulum. The posterior cingulum is prominent. The metaconid is more stout than on M₁ but more compressed

anteroposteriorly. The protoconid is also compressed. The posterior arm of the protoconid runs almost buccally. The base of that arm reaches to the lingual border of the tooth but does not connect to the metaconid so that the valley between it and the metaconid opens lingually. The mesoconid is small and has a buccal projection as in M₁. No mesolophid is present. The metalophid II is also transverse. The valley between the hypoconid and the protoconid is wide, but is blocked buccally by a small, thin ridge.

In M₃, the buccal part of the anterior cingulum is shorter than in M₂. No lingual part of the anterior cingulum is present. The posterior arm of the protoconid is short and the hypoconid is smaller than in M₂. No buccal projection on the mesoconid is seen. The valley between the protoconid and the hypoconid is wide and opens buccally. The posterior cingulum is prominent.

Discussion.—A new species of *Eumys*, *E. planidens*, was established on the basis of a single specimen (Univ. Colo. No 19810, a left ramus of mandible with M₂-M₃) by Wilson in 1949. Galbreath (1953) reported two additional lower jaws with M₁-M₃. The diagnostic features seen in the molars are ridges and cusps of grinding surface of cheek teeth rising to a nearly common plane. The specimens at hand show exactly the same characteristic features as the holotype of *E. planidens*.

The anteroposteriorly compressed cusps and thin ridges are characteristic of *E. planidens* and are not seen in any other species of *Eumys* described. Galbreath once stated that *E. planidens* may eventually be removed from the genus (Galbreath, 1953:74). Martin (1972) followed this argument and established a new genus for "*Eumys*" *planidens*. This should be published in the near future.

Three specimens of *Eumys planidens* have been reported. Galbreath (1953) described the morphological variation seen in the anteroconid of M₁. The present Badwater specimens show a greater variation than he recognized. He also mentioned an interesting variation seen in M₃ as follows: "In them, the posterior protoconid arm does not extend transversely beyond the mesoconid crest, whereas the type specimen has this arm extending to the internal

border." (His mesoconid crest must be called the entoconid crest, because no mesoconid or mesolophid is present at all on M_3 .) On M_3 of the holotype of this species, the internal border between the internal extremities of the metaconid and the entoconid is concave internally making the posterior arm of the protoconid shorter than the entoconid crest even if this posterior arm extends to the internal border. But on the holotype, the grinding surface of this posterior arm is shorter than that of the entoconid crest so that this arm does not extend beyond the mesoconid crest. The base of the protoconid posterior arm extends to the lingual border so that the base of it is longer than the grinding surface. This situation is rather close to that in Galbreath's specimens.

Wilson (1949) stated in the description of the holotype that on M_2 and on M_3 the posterior arm of the protoconid is closely related to the metaconid. On M_3 , the posterior arm of the protoconid runs linguad between the metaconid and the entoconid but slightly closer to the metaconid so that the valley between the metaconid and the protoconid posterior arm is narrower than the valley between the latter and the entoconid. Even so the posterior arm of the protoconid does not unite with the metaconid. On M_2 of the holotype, the posterior arm of the protoconid is connected to the metaconid and the basin between the metalophid and the anterior arm of the protoconid on the one hand and the posterior arm of it on the other hand is blocked completely. Galbreath (1953) gave the description of the posterior arm of the protoconid as follows: the posterior protoconid arm is long and free, but closer to the metaconid than the entoconid. The Badwater specimens of M_2 show variation in length of the posterior protoconid arm; on more specimens, it runs between the metaconid and the entoconid, closer to the former but free and does not reach to the lingual border of the tooth; on some (CM 33045 and 33053) it nearly reaches to the lingual border. Most specimens have no metastylid but on one specimen (CM 33048) a tiny but distinct metastylid is seen on the lingual border just linguad to the posterior proto-

conid arm, which does not extend to the lingual border of the tooth.

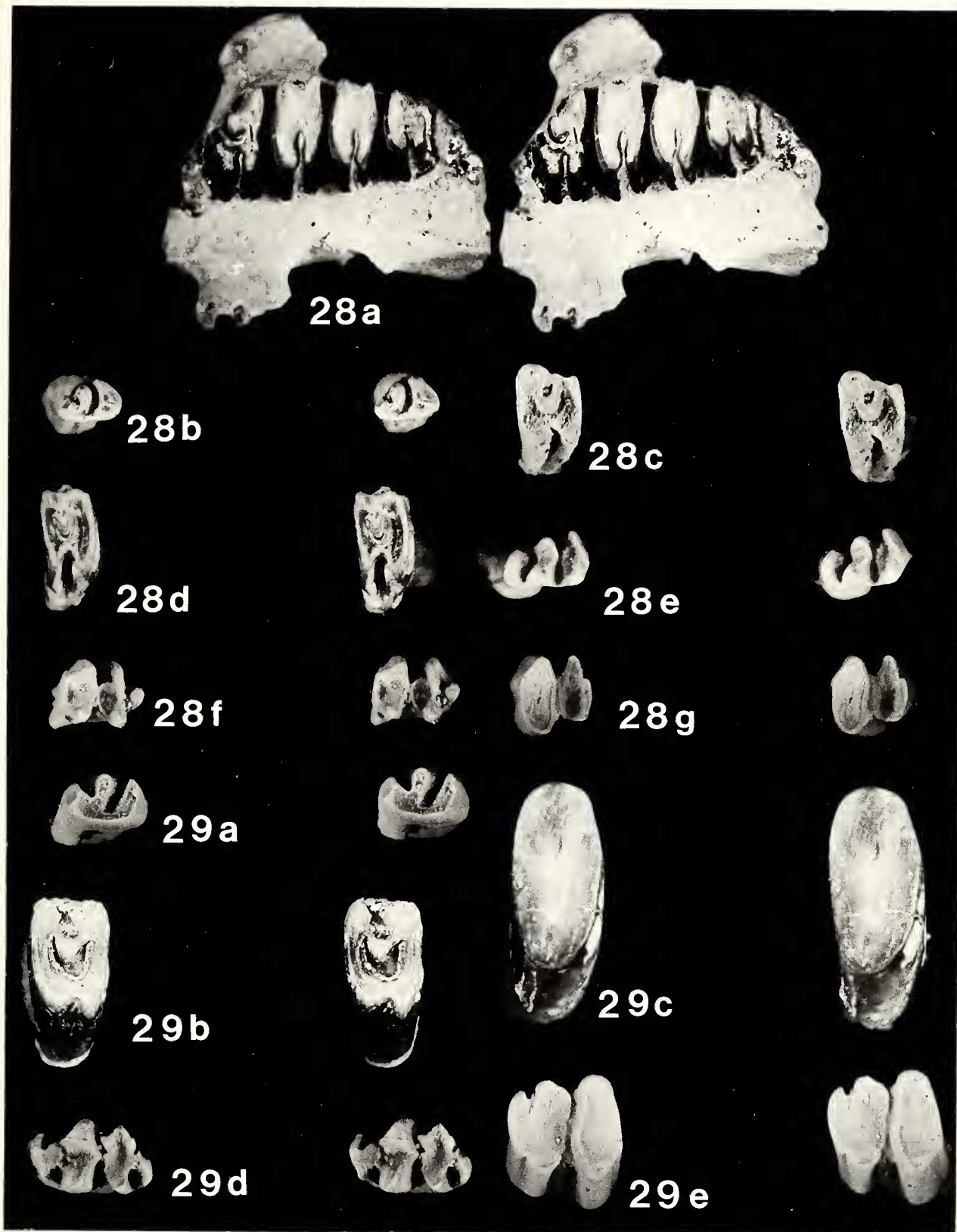
On M_2 of the holotype, the entoconid and the hypolophulid lingual to its union with the ectolophid form a straight transverse ridge but the hypolophulid buccal to the ectolophid (= the anterior arm of the hypoconid) runs posterobuccally forming a thin ridge. So these two ridges join with an angle at their union with the ectolophid. On the Badwater specimens, these two ridges form a straight line without an angle making a straight transverse hypolophulid.

Carnegie Museum of Natural History has a few undescribed specimens referable to *Eumys planidens* from Toadstool Park, Nebraska, Orellan, or the middle Oligocene in age. On some of the referable M_2 s, the posterior arm of the protoconid does not connect to the metaconid even if the former is close to the latter. This condition is rather close to the Badwater specimens. On all teeth from the Toadstool Park referable to M_2 , the hypolophulid lingual to the ectolophid joins the anterior arm of hypoconid at an angle as seen in the holotype. In all the species of *Eumys* except for "*Eumys*" *planidens*, the hypolophulid lingual to the ectolophid joins to the hypoconid anterior arm at an angle so that the situation seen in the holotype of *E. planidens* is close to the generalized forms of *Eumys* species. Although there is a considerable time span between the middle to the late Oligocene, the present forms are best described as *Eumys* sp. cf. *Eumys planidens*.

Order Lagomorpha
Family Leporidae Gray, 1821
***Palaeolagus burkei* Wood, 1940**
(Fig. 28, Table 13)

Referred specimens.—skull: CM 33967; DP²: CM 33968–33977; DP³: CM 17075, CM 33978–33998; P³-P⁴: CM 34035, CM 34036; P³-M²: CM 34037; P³: CM 33999–34008; DP⁴ and P⁴: KU 16631; DP⁴: CM 34009–34029; P⁴: CM 19712, CM 34030–34034; M¹: CM 18267, CM 34038–34042; M²: CM 34043–34050; DP³: CM 34051–34059; P₃: CM 18269, CM 34060–34077; DP₄: CM 34078–34093; P₄: CM 34094–34100; M₁: CM 17075, CM 34101–34103.

Fig. 28.—*Palaeolagus burkei*. a: CM 39037, left P³-M², ×5. b: CM 38968, right DP², ×8. c: CM 38980, right DP³, ×8. d: CM 39011, right DP⁴, ×8. e: CM 39051, right DP₃, ×8. f: CM 39081, right DP₄, ×8. g: CM 39101, right M₁, ×8. Fig. 29.—*Palaeolagus* sp. cf. *P. intermedius*. a: CM 39105, right DP². b: CM 39107, left DP⁴. c: CM 39108, right M¹. d: CM 39109, right DP₂. e: CM 39110, right M₂, ×8.



Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—The skull is flat. The braincase is not inflated. The plane of the palate is not bent on the basicranial axis, and the angle between the plane of the palate and the basicranial axis is small. The snout is very narrow and slender.

On DP², the tooth has two anterior re-entrants; one is on the anterobuccal corner of the tooth and crosses one-third or one-fourth of the occlusal surface; the other is situated lingual to the midline of the tooth and crosses almost two-thirds of the occlusal surface. The latter re-entrant persists to the base of the tooth whereas the former does not extend to the base of the tooth and will be obliterated in an earlier stage of wear. A small and shallow posterolingual re-entrant is observed, which will also be obliterated with wear. The enamel is well developed lingually and is reduced buccally.

Several specimens are identified as DP³. In these, the tooth has buccal roots. An isolated crescent is present between the central and lingual lobes. The anterior extension of the crescent is longer transversely than the posterior one. The enamel is thicker anteriorly than posteriorly. Cement is weakly developed.

The anterior loph of P³ is narrower transversely than the posterior loph. Following moderate wear, the tooth has an internal, straight walled hypostria crossing about one-third of the occlusal surface. A J-shaped crescent has a connection to the anterobuccal side of the tooth. Following further wear, the hypostria becomes shortened and the crescent completely worn away.

Several deciduous upper fourth premolars are recognized. One of them (KU 16631) is a DP⁴ with unerupted permanent P⁴ underneath. These two teeth were carefully separated. DP⁴ has buccal roots, but they are short and weak. The anterior loph is a little narrower transversely than the posterior loph. An isolated crescent which is concave buccally is retained between the central and lingual lobes. Another small, circular crescent is present just inside and a little buccal to the convex crescent just mentioned above. These crescents will be obliterated with further wear. On most specimens, the hypostria are straight-walled, but on some specimens (for example KU 16631) the posterior wall is crenulated. The enamel is well developed on its anterior and lingual sides, reduced on the buccal side, and absent on the posterior side and on the posterobuccal corner of the tooth.

On an unworn specimen of P⁴ (KU 16631), the anterior loph is slightly narrower than the posterior loph. The crown is square-shaped but will be elongated transversely with wear. The central lake is elongated anteroposteriorly but does not have a connection to the anterobuccal side of the tooth. The hypostria is straight-walled but at an unworn stage the anterior and posterior walls meet with an angle nearly 90°. With wear the hypostria becomes narrower. The enamel is thicker anteriorly than posteriorly. The buccal wall is formed by thin enamel, but with further wear the enamel becomes absent.

When worn, P⁴, M¹, and M² resemble one another in pattern. The crescent is completely worn away. In occlusal view each of these teeth has an internal, straight-walled hypostria crossing nearly one-half of the occlusal surface. The teeth become narrower transversely from P⁴ to M².

On DP³, there are three main lobes. The central lobe is the tallest when unworn. The posterior lobe is the widest transversely. The enamel is developed on the anterior face of the anterior lobe and the posterior face of the central lobe. No separation by an enamel and between the anterior and the central lobes is seen

even when unworn. The posterior lobe is completely surrounded by enamel when unworn. With slight wear, the anterior and the central lobes unite together forming a single lobe clearly separated from the posterior lobe. With further wear, anterior lobe and the posterior lobe unite, first in the middle of the tooth and next on the lingual side, leaving a small enamel lake on the lingual side of the tooth. The small lake will be lost with further wear.

P₃ has only two lobes. The talonid is wider transversely than the trigonid. After wear the internal re-entrant between the trigonid and talonid is retained. A shallow groove is present on the anterobuccal corner of the trigonid. This groove runs all the way down to the base of the tooth.

On DP₄, the tooth has two main lobes and a small accessory one. The anterior lobe is the trigonid and the second one is the talonid. The small accessory lobe is the hypoconulid. On unworn teeth, the hypoconulid is separated by enamel from the trigonid but soon they unite and the hypoconulid will be obliterated. The union of the trigonid and the talonid is solely by cement as in P₄.

P₄, M₁, and M₂ resemble one another in pattern. No unworn specimens referable to P₄ are available. Worn specimens have only two lobes. One specimen (KU 16630) has an almost unworn DP₄ and unworn M₁ *in situ* in the same individual. The unworn specimen of M₁ has a tiny hypoconulid posterior to the talonid. The hypoconulid is smaller than the corresponding cusp on DP₄ and is especially narrower transversely. This cusp on M₁ will be obliterated with further wear. Although no unworn materials of P₄ are known, I assume that P₄ has the hypoconulid posterior to the talonid when unworn, because DP₄ and M₁ have a clear hypoconulid before wear.

M₃ consists of two small lobes of which the posterior one is the smallest.

Discussion.—The present form is directly comparable to the materials described by Wood (1940) and Dawson (1958). On P₂, although shallow, the anterior re-entrant is persistent to the base of the tooth. This characteristic feature is seen in *Palaeolagus burkei*, but not seen in *P. hypsodus*. In this respect, the present form is closer to *P. burkei* than to *P. hypsodus*.

Palaeolagus sp. cf. *P. intermedius*

Matthew, 1899

(Fig. 29, Table 13)

Referred specimens.—DP²: CM 34104–34106; DP⁴: CM 34107; M¹: CM 34108; DP³: CM 34109; M₂: CM 34110.

Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Description.—These teeth are larger than those of *Palaeolagus burkei*. A DP² is tentatively referred to this species. The tooth has two anterior re-entrants; one is on the anterobuccal corner of the tooth, and the other is just lingual to the midline of the tooth and crosses almost two-thirds of the occlusal surface. The latter re-entrant is persistent to the base of the tooth. The enamel is well developed posteriorly and lingually but reduced buccally.

The material referable to DP⁴ is larger than the corresponding

Table 13.—Dimensions of teeth of *Palaeolagus burkei* and *Palaeolagus sp. cf. P. intermedius*.

<i>Palaeolagus burkei</i>																				
	DP ²		DP ³			P ³			DP ⁴			P ⁴			M ¹			M ²		
	L	W	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW
N	4	4	5	5	5	5	5	5	6	6	6	4	4	4	4	4	4	4	4	4
OR	1.40–0.98–		1.23–	1.52–	1.98–	1.49–	1.50–	1.99–	1.30–	1.86–	1.74–	1.39–	1.74–	1.87–	1.46–	2.43–	2.67–	1.21–	2.14–	1.93–
Mean	1.60	1.13	1.50	1.76	2.30	1.67	1.93	2.85	1.56	2.49	2.43	1.82	2.96	3.09	1.65	2.83	3.03	1.41	2.53	2.24
	1.540	1.035	1.402	1.658	2.116	1.568	1.776	2.432	1.400	2.103	2.067	1.600	2.353	2.450	1.550	2.610	2.813	1.303	2.273	2.010
<i>Palaeolagus sp. cf. P. intermedius</i>																				
	DP ²		DP ³			P ³			DP ⁴			P ⁴			M ¹			M ²		
	L	W	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW	L	AW	PW
N	3	3							1	1	1				1	1				
OR	1.91–	1.29–							1.98	2.62	2.84				2.22	4.30	—			
Mean	2.20	1.42							2.067	1.340										

tooth of *P. burkei*. The general morphology agrees with that of *P. burkei*.

The upper molars are also larger than those of *P. burkei*. The hypostria is shallower than in *P. burkei*, and on worn specimens the hypostria almost vanishes. Only a shallow groove remains on the posterolingual face of the tooth.

On DP³, there are three lobes and a small accessory one. The anterior three lobes resemble those seen in DP₃ of *P. burkei*. The accessory one is half as wide transversely as the posterior lobe. The morphology of the remainder of the crown agrees with that seen in *P. burkei*.

Discussion—Based on its larger size and the shallow hypostria, these specimens are referred to *P. intermedius*.

Order Carnivora
Family Canidae Gray, 1821

Hesperocyon temnodon (Wortman and Matthew, 1899)

(Fig. 30, Table 14)

Referred specimen.—CM 21678.

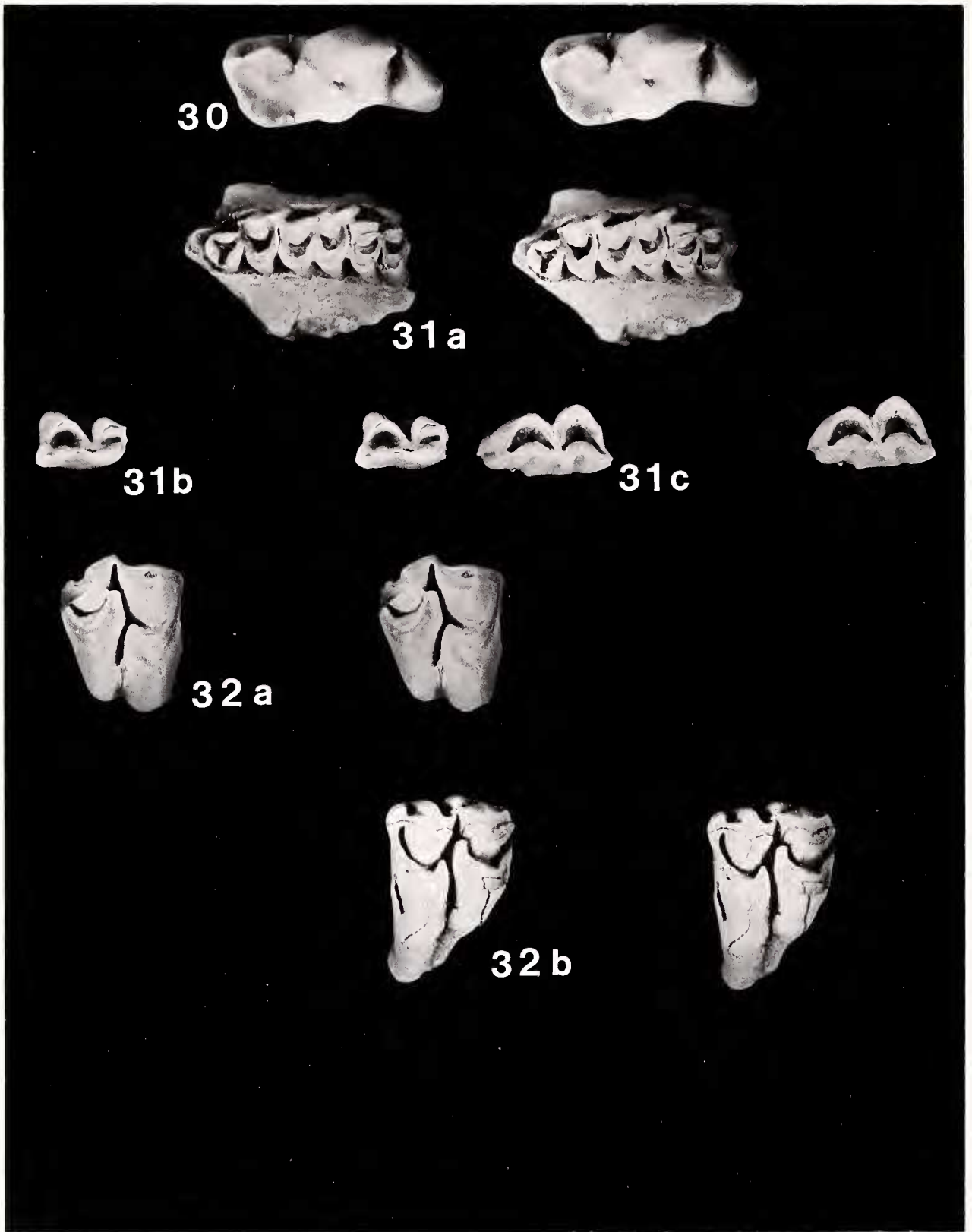
Locality.—Loc. 19, Badwater Creek, Wyoming.

Age.—Late Oligocene.

Discussion.—Only one specimen referable to this species is available. Matthew (1901:357) referred a specimen from the *Leptauchenia* zone in Logan County, northeastern Colorado, to this species, but he did not describe the specimen. Galbreath

Table 14.—Dimension of teeth of *Hesperocyon temnodon* and *Leptomeryx sp. near L. evansi*.

Sta- tistics	M ¹			M ²			M ₁		
	L	AW	PW	L	AW	PW	L	AW	PW
<i>Hesperocyon temnodon</i>									
N							1	1	1
OR							9.88	4.25	4.16
<i>Leptomeryx sp. near L. evansi</i>									
N	1	1	—	1	1	1	—	—	—
OR	5.62	6.29	—	8.69	8.69	8.21	—	—	—



(1953:76) cited Matthews but also did not describe the material. *H. temnodon* was originally established by Wortman and Matthew (1899:130) as *Cynodictis temnodon* based on an upper dentition. Macdonald (1963:202) listed the characteristics of M_1 of *Hesperocyon* as: entoconid present; one or two enteroconids; deeply basined talonid; talonid closed posteriorly. The present specimen shows this morphology. In size it is smaller than *H. leptodus*. Tentatively, the present specimen is referred to *H. temnodon*.

Order Perissodactyla
Family Equidae Gray, 1821
Miohippus sp.

Referred specimen.—Astragalus: CM 21679.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Discussion.—An astragalus is the only equid specimen available. The size of the astragalus is clearly larger than that of *Mesohippus* and a little larger than that of *Miohippus equiceps* described and figured by Osborn (1918:324). No teeth referable to this genus are available. The specific identification is difficult.

Family Hyracodontidae Cope, 1879
Hyracodontidae genus indet.

Referred specimens.—Tooth and limb bone fragments: uncatalogued.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Discussion.—Small fragments of teeth and limb bones of hyracodont rhinoceros have been found, but nothing is generically determinable.

Order Artiodactyla
Family Hypertragulidae Cope, 1879
Leptomeryx sp. near *L. evansi* Leidy, 1853
(Fig. 32, Table 14)

Referred specimens.— P^3 : CM 21694; M^1 : CM 21695; M^2 : CM 21696; M_1 : CM 21693.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Discussion.—The materials at hand are too incomplete for specific identification. The size is very close to or a little larger than that of *Leptomeryx*

evansi. The tooth morphology is almost exactly the same. CM 21696 is a second upper molar where the buccal face of the metacone is not completely flattened but a small ridge runs vertically on the middle of the surface. This part of the enamel is slightly thickened so that the buccal face of the metacone is rather convex buccally. On most specimens of *L. evansi* which I examined the buccal face of the metacone is flat or slightly concaved.

Leptomeryx is a typically Oligocene genus. Scott (1940:537) stated, "It (= *Leptomeryx*) is one of the commoner fossils of the lower Brule (Oreodon Beds) and is much less frequently found in the upper Brule, or the Chadron. It persisted through the John Day and into the lower Miocene (Gering stage)." Occurrences of *Leptomeryx* from the lower Miocene were reported by Macdonald (1963:233) from western South Dakota and Martin (1972) from western Nebraska. The materials referable to *Leptomeryx* reported by them are again too fragmentary to warrant specific identification.

Hypisodus sp. near *H. minimus* (Cope, 1873)
(Fig. 31)

Referred specimens.— M^1 - M^3 : CM 21682; M^1 : CM 34111, CM 34112; M^2 : CM 21684, CM 21687, CM 34113; P_3 : CM 21688; M_1 : CM 21683, CM 21685, CM 21686, CM 21690; M_2 : CM 21689.

Locality.—Loc. 19, Badwater Creek, Wyoming.
Age.—Late Oligocene.

Description.—The size of the present form is a little larger than that of the holotype of *Hypisodus minimus*. A similar form has been reported by Scott (1940:535) from "the Uppermost Brule" of eastern Nebraska and by Galbreath (his Form B, Galbreath, 1953:91) from the Vista Member of the White River Formation of northeastern Colorado. On specimens of the present form, the upper molars have a weak buccal style, or a median rib on the anteroexternal crescent of Scott (1940:525) so that the vertical valley between the style and the parastyle is very shallow. But on a few specimens (CM 39111, M^1 and CM 21684, M^2), the upper molars have a fairly well-developed buccal style on the buccal face of the paracone so that the valley between it and the parastyle is fairly deep. The degree of the depth of that valley also depends on the orientation of the parastyle. On the specimens having a shallow valley, the parastyle projects rather anteriorly whereas the parastyle extends more anterobuccally on molars having a deeper valley. Thus, the degree of weakness of the buccal style on the buccal face of the paracone and the depth of the valley have a fairly wide range of variation.

Discussion.—*Hypisodus* has been thought to be restricted to the Oligocene. Martin (1972), however,

←

Fig. 30.—*Hesperocyon temnodon*. CM 21678, left M_1 , $\times 4$. Fig. 31.—*Hypisodus* sp. near *H. minimus*. a: CM 21682, right M^1 - M^3 . b: CM 21685, right M_1 . c: CM 21689, right M_2 . $\times 4$. Fig. 32.—*Leptomeryx* sp. near *L. evansi*. a: CM 21695, right M^1 . b: CM 21696, left M^2 . $\times 4$.

reported an occurrence of *Hypisodus* from the lower Miocene Gering formation of western Nebraska. His form is larger than any other known species of *Hypisodus*. He stated that the labial styles are low and flattened. As stated above, based on the present

samples at hand, the degree of development of styles varies from specimen to specimen. Size seems to be the only criterion for separating species of *Hypisodus*.

SUMMARY AND CONCLUSIONS

Besides a few lower vertebrates, only small mammals have been recovered from the upper Oligocene sediments along Badwater Creek. The preserved fauna of the Cedar Ridge local fauna is greatly biased by two major factors, which are wholly independent of each other; first, due to stream action, only small teeth and bones were transported and deposited at Loc. 19 so that larger mammals, which surely lived near the site of deposition during the late Oligocene are not represented in the fauna; second, due to drier climatic conditions along Badwater Creek in late Oligocene time, only land animals, which were adapted to such kind of ecological conditions, could live there and consequently these animals are represented in the fauna, whereas the animals, which required more mesic conditions, could not have lived there and therefore they are not represented in that fauna.

The drier climatic condition along Badwater Creek in the late Oligocene is indicated by the presence of calcic feldspars and evaporites throughout the section. These were formed under a climatic regime with moderate temperatures. Although no botanical evidence has been recovered, the environmental situation is thought to be of a grassland, steppe to semidesert type with low precipitation and moderate temperature.

Due to unfavorable ecological conditions, land micromammals, which lived there during late Oligocene time, were specialized in having higher crowned and more lophate teeth. This was the result of adaptation to a more herbaceous diet in drier climatic conditions. Some of the rodents represented had more hypsodont teeth than in their middle Oligocene counterparts, but they have never developed rootless or everygrowing cheek teeth.

Among rodents, many specialized eomyids are the most common constituents of the Cedar Ridge local fauna. Eomyids appear to have had their major North American radiation during the early Oligocene. Wilson (1949:112) pointed out that the tooth pattern in eomyids is similar to, although not identical with, the cricetodont pattern. As Black (1963:41) has stated, it is quite possible that mem-

bers of the Eomyidae occupied many of the same habitats that were later filled by the cricetids. Only a few cricetids are at present known from the early Oligocene when the major radiation of the Eomyidae took place (Clark, et al., 1964). It seems possible that many of the early Oligocene eomyids such as *Yoderimys*, *Centimanomys*, *Namatomys*, and *Aulolithomys* were replaced by the more highly specialized cricetids during Chadronian time. Eomyids became abundant and varied in the late Oligocene perhaps through adaptation to drier climatic conditions and more open environmental situations. Eomyine cricetids are abundant in the Orellan and by the Arikareean, a number of cricetid types are known. Most of them, however, required more mesic conditions and surely lived under a more hospitable climate in present Oregon and Nebraska. Among cricetid rodents, *Leidyms*, *Paciculus*, and *Scottimus* are known from the late Oligocene of Oregon and Nebraska, but they are not represented in the Cedar Ridge local fauna. Highly specialized eomyids and also a few highly specialized cricetids coexisted in the Badwater Creek area during the late Oligocene time.

Near the Oligocene-Miocene boundary, the environment returned to a more mesic condition with considerable precipitation. In relation to the climatic changes, the highly specialized eomyids and cricetids, which were adapted to drier conditions, could not survive and most of them became extinct by the end of the Oligocene. Subsequently, cricetids represented by *Leidyms*, *Paciculus*, and *Scottimus* expanded during the Miocene.

An eomyine genus, *Pseudotheridomys*, is represented in the North American early Miocene by *P. hesperus* (Wilson, 1960) from the Martin Canyon Quarry A fauna. This species, however, is closely related to European forms and evidently represents an early Miocene immigration into the New World. Thus, most of the North American Oligocene eomyids became extinct by the end of the Oligocene and a few forms could have survived into Miocene time.

It is worth discussing whether any new forms

migrated into North America from some other center of radiation during the Oligocene. Based on the study of the late Eocene Badwater local fauna, Black, (1967:63) stated, "Many groups that made their first appearances in the late Eocene may represent immigrants from other areas and thus were not present in earlier North American faunas." I agree with his conclusion. Thus, many groups represent immigrants into North America from other areas in the late Eocene. Now we have to consider whether any forms represent immigrants during the Oligocene.

The eomyids were probably descended from members of the Sciuiravidae (Black, 1965:42), sometime during the latter half of the Eocene, but their ancestors are not known as yet. The number and diversity of eomyids now known from the early Oligocene would seem to indicate either a much greater late Eocene radiation in North America than has been recognized to date or a considerable immigration into western North America in the latest Eocene from some other center of radiation. Only *Adjidaumo* and *Paradjidaumo* persist into the middle Oligocene and, by the end of the Oligocene a number of specialized eomyids have evolved from the ancestral stocks of *Adjidaumo* and *Paradjidaumo*. The major Old World eomyid radiation evidently took place during the Aquitanian and Burdigalian (early to middle Miocene). As far as the North American eomyids are concerned, they evolved within the North American continent and they did not receive any new comers from outside North America although the possibility of an immigration from North America to Europe can not be ruled out. After the climate returned to a more hospitable condition in the late early Miocene, some European eomyids, for example, *Pseudotheridomys* (Wilson, 1960) and *Eomys* (Lindsay, 1974), migrated into North America. These forms are not descendents of the North American Oligocene eomyids.

The origin of the Cricetidae is not certain. It seems likely that the cricetids along with many other rodent families may be derived from late Eocene sciuravids. The North American Cricetidae are already abundant in the lowermost Orellan (Martin, 1972) in Nebraska. They are very close to certain Eurasian cricetids, notably *Eucricetodon* and *Pseudocricetodon*, and it seems likely that there was an exchange of cricetids between North America and Eurasia in the Chadronian (early Oligocene). As the

place of the origin of the cricetids is unknown, the direction of this exchange is not clear; however, it seems likely that it took place soon after the probable time of origin of the Cricetidae in the late Eocene. But, once the basal stocks of the cricetids had been established in North America sometimes during the early Oligocene, they evolved in North America and it seems likely that the cricetids replaced eomyids in large part during the middle Oligocene. *Cricetodon* has been described from the Upper Oreodon Beds (middle Oligocene) of Nebraska by Wood (1937:256). *Cricetodon* is a European genus and if the material described by Wood is referable to *Cricetodon*, it must represent an immigration from Europe into North America during the middle Oligocene. Close examination, however, shows that having the mesolophid longer than the posterior arm of the protoconid on M_1 and M_2 is seen not only in *Cricetodon*, as Wood believed, but in some other forms of North American cricetids as well, especially *Eumys elegans*. The material described by Wood thus does not represent an immigrant from Europe, but should be regarded as a variant of the North American *Eumys*-complex. All the North American late Oligocene cricetids have their ancestry in the middle Oligocene of North America (Martin, 1972).

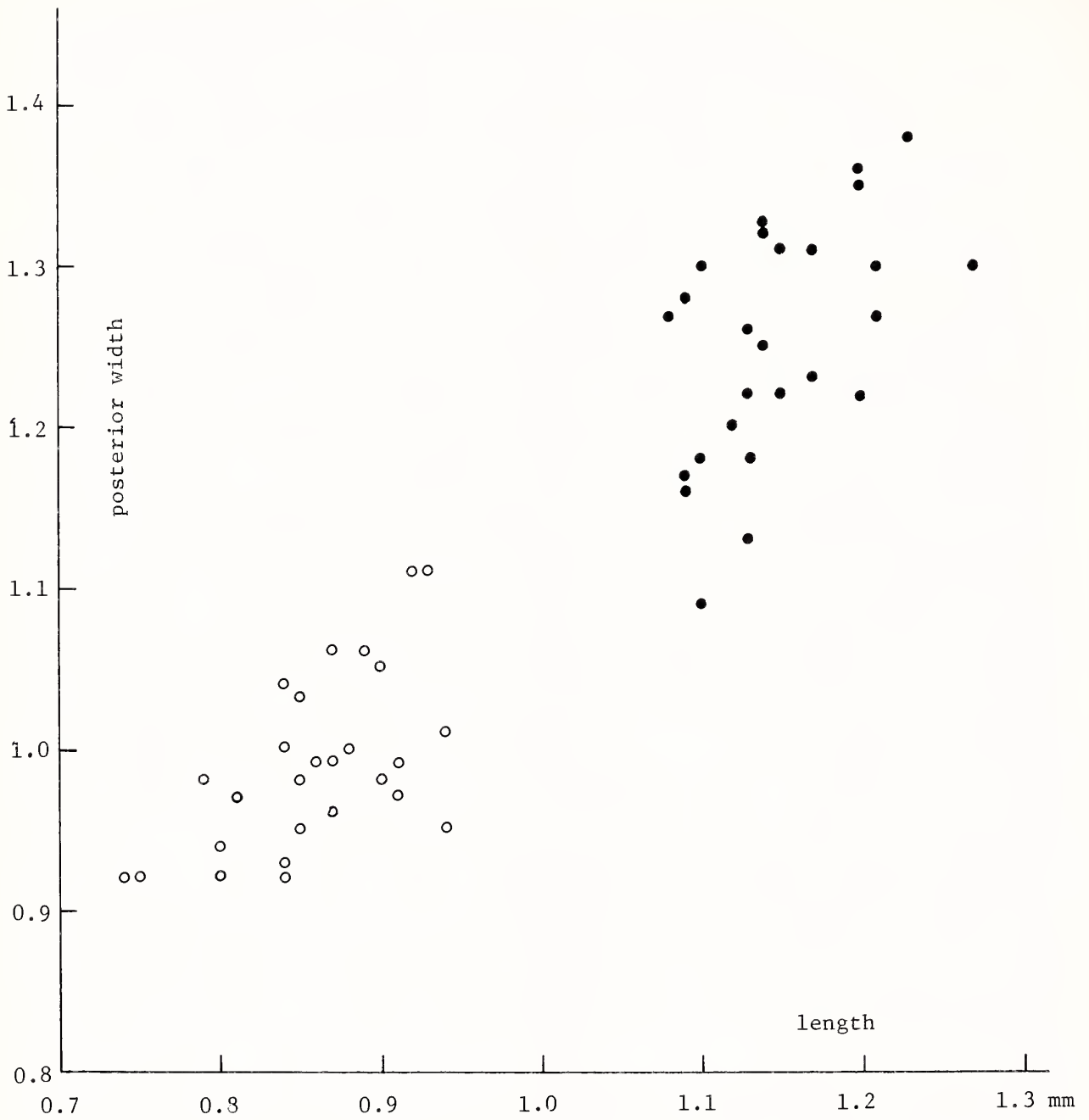
The other rodents and insectivores in the Cedar Ridge local fauna have their ancestry in the middle and even in the early Oligocene of North America. Thus, the late Oligocene mammal fauna represented by the Cedar Ridge local fauna has a close relationship to the middle Oligocene faunas of North America and no great faunal gap between them is recognized. Because most of the "typical" North American Oligocene eomyids and some cricetids became extinct by the end of Oligocene and some forms migrated into North America during the Miocene, a more distinct faunal gap is recognized between the late Oligocene and the early Miocene faunas than between the middle and the late Oligocene faunas.

The rodent families Castoridae (beavers), Mylagaulidae (mylagaulids), and Aplodontidae (aplodontids besides *Prosciurus* and *Pelycomys*) are almost always found in faunas of the early Miocene of North America. They are totally absent from the Cedar Ridge local fauna and this makes the faunal distinction clearer, between the late Oligocene and the early Miocene faunas.

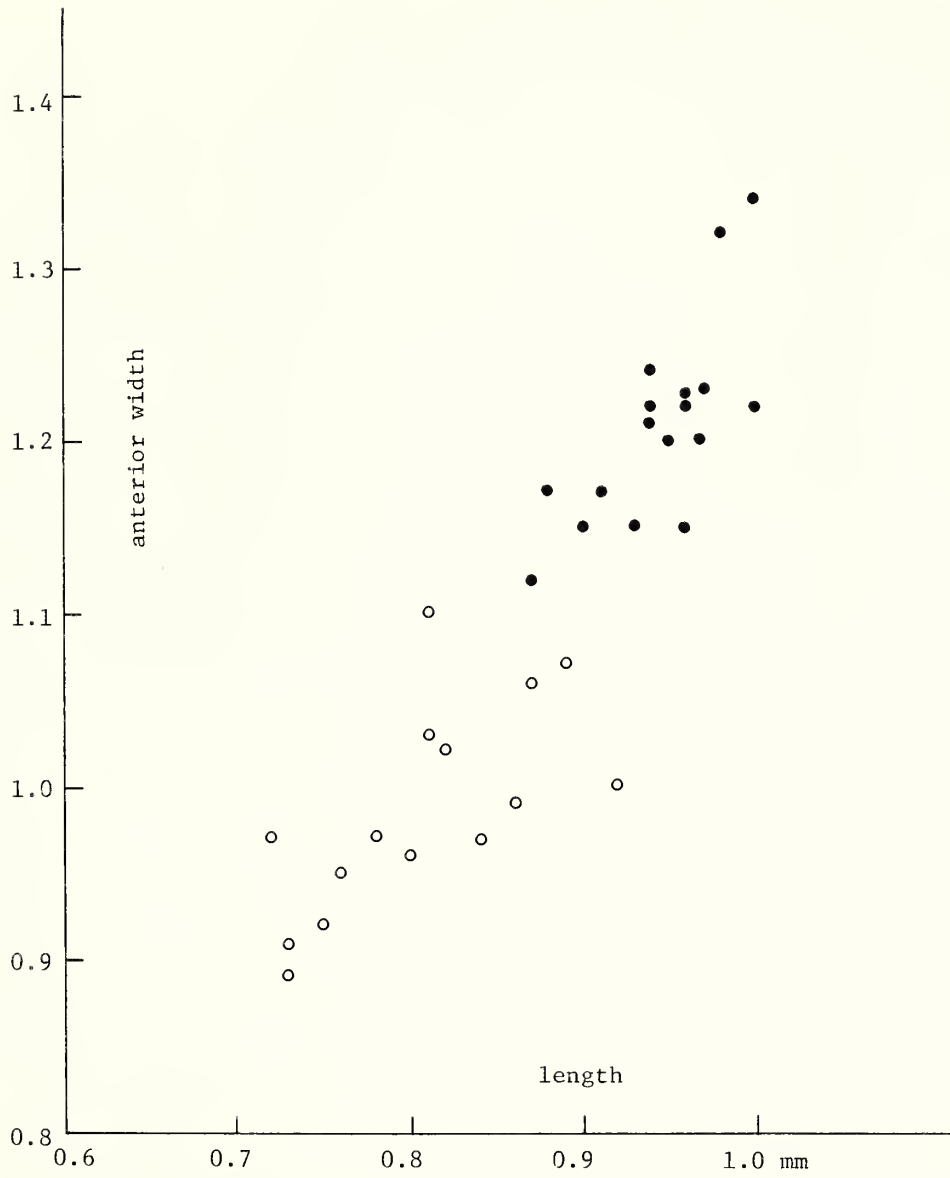
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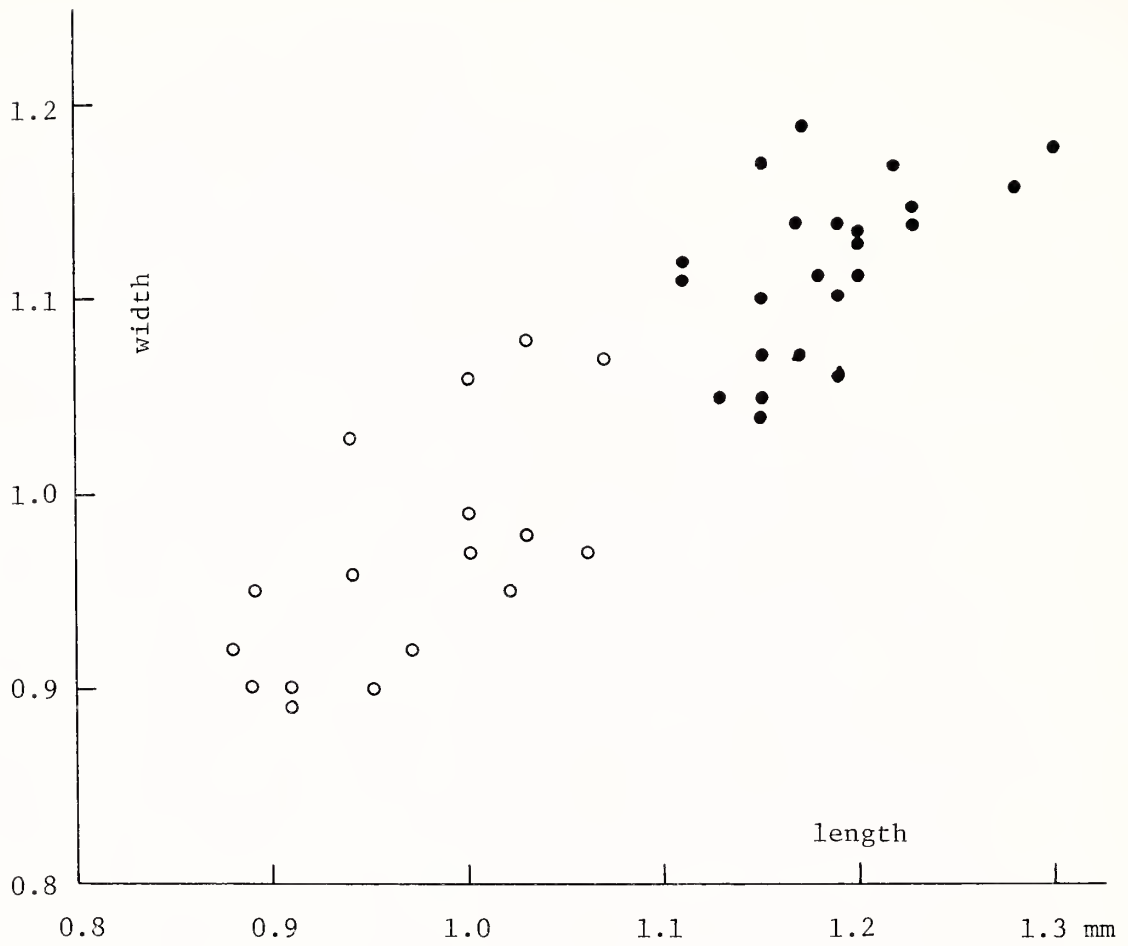
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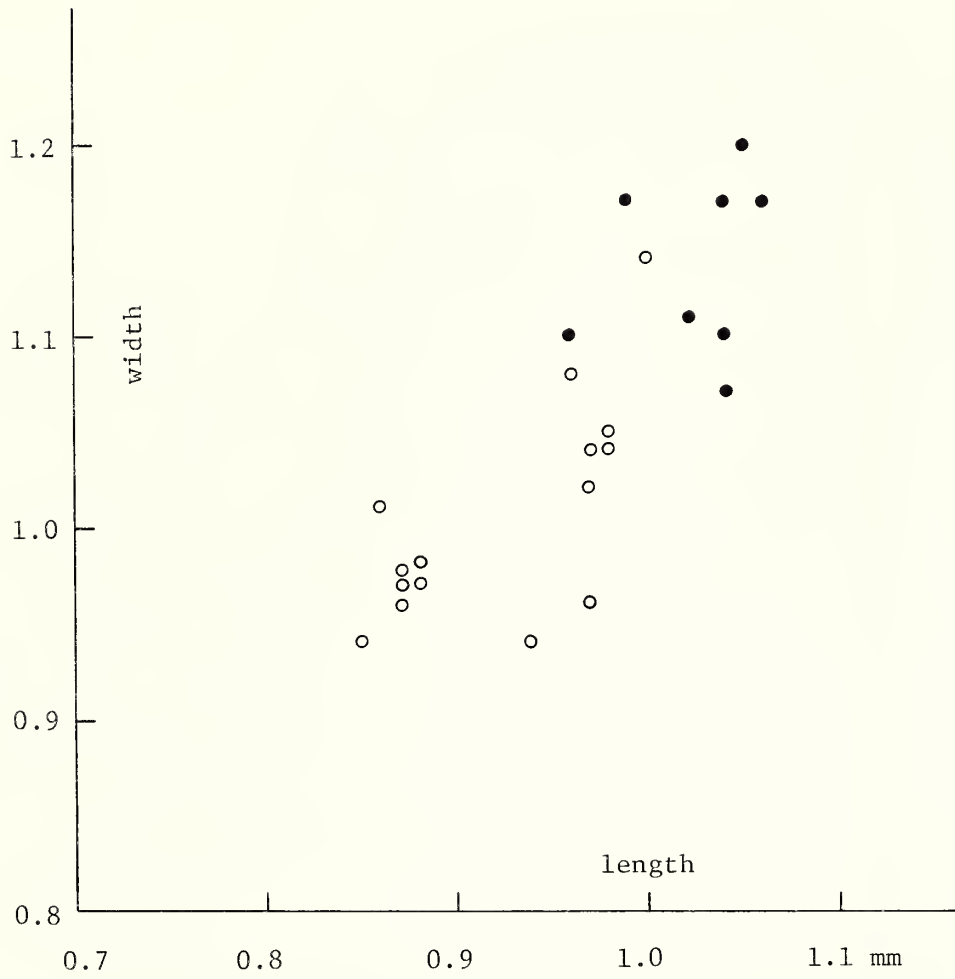
Appendix A.—Size-frequency graph of M^1 of heteromyids. Closed circles, *Proheteromys*; open circles, *Heliscomys*.



Appendix B.—Size-frequency graph of M^2 of heteromyids. Closed circles, *Proheteromys*; open circles, *Heliscomys*.



Appendix C.—Size-frequency graph of M₁ of heteromyids. Closed circles, *Proheteromys*; open circles, *Heliscomys*.



Appendix D.—Size-frequency graph of M_2 of heteromyids. Closed circles, *Proheteromys*; open circles, *Heliscomys*.